# Appendix E

# Communication Between U.S. Nuclear Waste Technical Review Board and U.S. Department of Energy

In addition to published reports, the Board periodically writes letters to the Director of the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The letters typically provide the 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 the OCRWM. For archival purposes, the eight Board letters written during the period covered by this report are reproduced here.

The OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are the OCRWM's responses received by the Board during calendar year 2003. Inclusion of these responses does not imply the Board's concurrence.

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; March 5, 2003.
  Subject: DOE's participation at the January Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; June 26, 2003.
  Subject: DOE's responses to recommendations in the March 5, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; April 30, 2003.
  Subject: DOE's participation at Panel on the Waste Management System meeting on transportation issues held February 24, 2003

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; July 22, 2003.
  Subject: DOE's responses to recommendations in the April 30, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; June 27, 2003.
  Subject: DOE's participation at Panel on the Natural Systems and Panel on the Engineered System meeting on seismic issues held February 24, 2003

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; October 8, 2003.
  Subject: DOE's responses to recommendations in the June 27, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; June 30, 2003.
  Subject: DOE's participation at the May Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; October 10, 2003.
  Subject: DOE's responses to recommendations in the June 30, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; October 21, 2003. Subject: Board comments the data and analyses presented at the May Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; October 27, 2003. Subject: DOE's responses to recommendations in the October 21, 2003 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; November 25, 2003. Subject: Transmittal of Board technical report

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; December 17, 2003. Subject: DOE's responses to recommendations in the letter of October 21, 2003 and report of November 25, 2003

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; December 4, 2003. Subject: Board January panel meetings

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; December 16, 2003. Subject: DOE's participation at the September Board meeting

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

March 5, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the U.S. Nuclear Waste Technical Review Board, I want to thank you for participating in the Board's meeting on January 28, 2003, in Las Vegas, Nevada. We found your program overview and the presentations by individuals from the Department of Energy (DOE) and its contractors very clear and helpful to the Board in carrying out its responsibility to review the scientific and technical validity of DOE activities. The Board's observations and several recommendations drawn from the information presented at the meeting are summarized below.

**Natural Barriers**

Encouraging the DOE to develop a better fundamental understanding of the potential behavior of the natural barriers in a Yucca Mountain repository has long been a Board priority. Two presentations at the meeting dealt with issues that have relevance for such understanding.

*Chlorine-36* – The Board previously has recommended that the DOE resolve the contradictory analyses related to the possible presence of bomb-pulse chlorine-36 at the repository horizon. The Board realizes that the DOE's conceptual and numerical models for flow and transport in the unsaturated zone attempt to reduce the relevance of the contradictions by assuming the presence of fast flow paths in the unsaturated zone. However, the Board believes that developing a basic understanding of key processes inside Yucca Mountain that may affect repository performance is essential. This understanding should include whether or not fast flow paths are present in the unsaturated zone and the extent of rapid water movement through the fast paths if they do exist. In addition, discrepancies in results between two DOE-supported groups measuring the same phenomenon affect the credibility of the program. The Board continues to believe that the DOE should persist in its efforts to reach scientific consensus on the results of the chlorine-36 analyses and the implications of those results for fluid flow in Yucca Mountain.

*Paleosols* – Field investigations and numerical modeling of heterogeneous alluvial sedimentary deposits show that even relatively thin low-permeability deposits can significantly alter directions and rates of water flow and chemical transport in the saturated zone. Ancient soils known as "paleosols" can form these thin low-permeability deposits within alluvial

sedimentary sequences and are known to occur in the Yucca Mountain region. Also, depending on their mineralogical properties, paleosols can potentially retard the chemical-transport rates of some radionuclides. Taken together, these characteristics suggest that paleosols merit exploratory investigation by project hydrogeologists.

**Engineered Barriers**

As noted in previous Board reports and letters, uncertainties related to the performance of the engineered barriers are extremely important, particularly given the prominence of the engineered barriers in DOE estimates of repository performance and DOE's decision to use a high-temperature repository design in its license application. Several presentations at the meeting dealt with factors that could affect the potential performance, development, or procurement of the engineered barriers in a Yucca Mountain repository.

*Corrosive environments* – Contractors for the State of Nevada presented experimental results showing that highly corrosive brines and condensates can be produced at laboratory scale by distillate boiling of concentrated synthetic porewaters at atmospheric pressure. However, the presentations did not include a specific sequence of events that would cause such corrosive solutions to develop in a repository at Yucca Mountain. The presentations also did not include estimates of the likelihood that such solutions would occur in a repository or of the extent of such solutions if they were to occur. Dr. Joseph Farmer gave a very informative presentation on the Project's view that the evolution of such highly corrosive environments in a repository at Yucca Mountain would be unlikely. Except in the case of acid-gas generation, however, his presentation did not include the Project's technical basis for this view (i.e., that the generation of certain highly corrosive solutions would be either implausible or so unlikely or minor in extent as to be insignificant).

Clearly, corrosive solutions are *possible*; the necessary porewater, decay heat from the waste packages, and in-drift conditions (i.e., high temperatures, pressure, humidity) would be present in a repository at Yucca Mountain. However, the Board does not know, at this point, whether a case can be made that corrosive solutions would be so likely and widespread that they would be a concern or whether a case can be made that they would be so unlikely and sparse that they would be insignificant. Presentations convey data, views, and progress, but complex hypotheses and models require carefully prepared and reviewed technical reports for their explanation and defense. Thus, we urge the Project to ensure that the analysis and model report (AMR) that deals with the evolution of chemical environments on waste package surfaces contains a defensible technical basis, including the full logic, explanations, and assumptions underlying the Project's view that widespread corrosive solutions are unlikely.

We asked at the meeting whether a repository with lower peak temperatures of waste package surfaces would reduce the uncertainty, likelihood, or severity of corrosive solutions. However, the question was not answered directly. The Board believes that the Project should answer this question, and, if the answer is "Yes," a second question, "How much?" also should be answered. The technical basis for both answers should be documented carefully and completely in an AMR.

*Materials studies* – The Board was encouraged by the information presented on studies of corrosion in the presence of deliquescence, seepage, and $CaCl_2$ brines, but we note that many more studies, especially at elevated temperatures, will be needed to adequately explore potential corrosion mechanisms and corrosion rates in a high-temperature repository. The Board concurs with the observation of the Waste Package Materials Performance Peer Review Panel that the Project staff needs a senior-level, visionary leader with a strong background in materials science and engineering and with very good management credentials. Such a person could develop a systematic approach for identifying needed materials studies, ensure continuity of the effort, and enhance communication with the technical community.

*Prototype manufacturing* – The Board is pleased that the DOE plans to procure waste package prototypes and develop welding processes. Programs in other countries that have undertaken prototyping activities have learned a great deal. In fact, some programs have encountered surprises that have taken considerable time to resolve. Manufacturing waste packages to the specifications required for a repository may require a significant development effort and corresponding lead-time before repository operations can begin. Information presented at the Board meeting did not contain detailed justification for the number of prototypes planned, but the Board concurs with the timing of the initial development effort. The Board strongly urges the DOE to begin prototype development as soon as possible.

As experience is gained, useful modifications of the waste package design may be identified. For example, the DOE may find that dual Alloy-22 lids may not be justified in light of the manufacturing complexity associated with a dual-lid design. The current plan not to stress-relieve or otherwise mitigate tensile stresses of the inner Alloy-22 closure weld also raises questions about the value of the dual-lid concept. Finally, because the trunnion-collar sleeves appear complex and their attachments to the waste package appear prone to crevice corrosion, there may be a need to reconsider these parts of the design during prototype manufacturing.

**Repository System and Integration**

The Board also has urged the DOE to gain a better understanding of the potential behavior of the entire repository system through continued scientific studies and through analysis of the contribution of different barriers to repository performance. Presentations at the meetings touched on these issues.

*Barrier performance* – The Board is pleased that the DOE continues exploring ways to determine and display the contributions of individual barriers to performance of the overall repository system. The Board believes that such analyses can provide important insights into the respective roles of the different barriers. Furthermore, there appear to be opportunities for improving both the analytical approach for analyzing the performance of individual barriers and the clarity of the presentation of study results. The Board urges the DOE to continue this effort.

*On-going scientific studies* – Results from scientific studies, such as experiments in the cross drift and the cool-down phase of the drift-scale heater test, may be very valuable in increasing understanding of the potential behavior of a repository system at Yucca Mountain. However, these studies will require adequate funding and the attention of management to realize

their true potential. As the Yucca Mountain project focuses on licensing activities, the temptation may be to divert resources from scientific studies to the licensing effort. The Board encourages the DOE to institute mechanisms that will ensure adequate funding and management commitments to on-going scientific studies.

**Waste Management System**

With the approval of the site recommendation, the DOE's plans for operating the waste management system, including waste acceptance, transportation, and operations at a Yucca Mountain repository, have become extremely important. Since funding constraints in this area have caused plans to be deferred for several years, the Board is pleased to see that the DOE will resume work on the waste management system this year. The Board views this as a very important area and will hold additional meetings to review DOE plans in the coming months.

The Board recommends that the transportation planning and development effort adopt a "systems" approach, addressing both strategic and operational considerations. The Board views the early involvement of external stakeholders as critical to developing a comprehensive plan for the waste management system and to building public confidence in those plans. Because proactive engagement of external stakeholders is a time-consuming process, the Board encourages the DOE to initiate this activity as soon as possible.

Once again, the Board thanks you, the DOE staff, and the DOE contractors for supporting the Board's January meeting. We look forward to continuing our ongoing technical and scientific review and to commenting on DOE activities in the future.

Sincerely,

[Signed By]

Michael L. Corradini
Chairman

**Department of Energy**
Washington, DC 20585

June 26, 2003

Dr. Michael L. Corradini, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of March 5, 2003, providing the Nuclear Waste Technical Review Board's (Board) perspective on information presented by the U.S. Department of Energy (Department) at the Board's January 2003 meeting.

The Department appreciates the Board's continuing review of our activities as we continue development of science, design, and analysis, including a license application, for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board, and we look forward to continuing our dialogue.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
*Responses to the March 5, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board*

**Responses to the March 5, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board**

*Natural System*

*The Board continues to believe that the DOE should persist in its efforts to reach scientific consensus on the results of the chlorine-36 analyses and the implications of those results for fluid flow in Yucca Mountain.*

**Response:**

The DOE agrees that it is important to resolve the discrepancies in results between two DOE-supported groups measuring the same phenomenon. As noted in our letter of January 24, 2003[1], DOE is pursuing resolution of the legacy discrepant data sets by

- having the institutions involved to date document the results to date and propose a plan to resolve the discrepancies, and
- considering an independent new validation study as a parallel, complementary effort.

Isotopic evidence of the existence of fast pathways has guided the development of the unsaturated-zone flow conceptual model which includes dual-permeability concepts that can capture the range of travel times corresponding to flow in the matrix and flow in fractures. The quantitative $^{36}Cl$ information has been compared with the numerical results of the model. The information is used as "supporting data" rather than as a target for model calibration. Even though the $^{36}Cl$ data were not used to calibrate the unsaturated flow model (CRWMS M&O 2000, Section 3.7.4.4[2]), the distribution of travel times predicted by the model is consistent with the data. The occurrence of some rapid transport has been built into the conceptual and numerical models of unsaturated-zone flow and transport to be consistent with isotopic evidence, and the TSPA calculations capture this behavior within the range of uncertainty in the existing isotopic data.

*Field investigations and numerical modeling of heterogeneous alluvial sedimentary deposits show that even relatively thin low-permeability deposits can significantly alter directions and rates of water flow and chemical transport in the saturated zone. Ancient soils known as "paleosols" can form these thin low-permeability deposits within alluvial sedimentary sequences*

---

[1] Chu, Margaret, 2003. Letter to Michael L. Corradini responding to the views expressed by the Board on information presented in the September 2003 NWTRB meeting, with enclosure. January 24, 2003.

[2] CRWMS M&O 2000c. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O.

*and are known to occur in the Yucca Mountain region. Also, depending on their mineralogical properties, paleosols can potentially retard the chemical-transport rates of some radionuclides. Taken together, these characteristics suggest that paleosols merit exploratory investigation by project hydrogeologists.*

**Response**:

At the January meeting, Dr. Graham Fogg from the University of California at Davis gave an interesting presentation[3] on the influence of paleosols on fluid flow and transport in complex alluvial sediments. The DOE will consider the merit of investigating paleosols in the alluvium along with other proposals for additional studies under consideration in the Science and Technology Program.

***Engineered Barriers Corrosive Environments***

*Contractors for the State of Nevada presented experimental results showing that highly corrosive brines and condensates can be produced at laboratory scale by distillate boiling of concentrated synthetic pore waters at atmospheric pressure. However, the presentations did not include a specific sequence of events that would cause such corrosive solutions to develop in a repository at Yucca Mountain. . . .* The *Board does not know, at this point, whether a case can be made that corrosive solutions would be so likely and widespread that they would be a concern or whether a case can be made that they would be so unlikely and sparse that they would be insignificant. . . . Thus, we urge the Project to ensure that the analysis and model report (AMR) that deals with the evolution of chemical environments on waste package surfaces contains a defensible technical basis, including the full logic, explanations, and assumptions underlying the Project's view that widespread corrosive solutions are unlikely.*

**Response**:

During the recent May NWTRB meeting, the DOE made an extensive set of integrated presentations[4] laying out why we believe that a strong case can be made for the efficacy of our current design approach. Both the in-drift environment and the corrosion resistance of the engineered barriers were discussed in detail. As usual, the interaction with the Board was very useful to us, because it brought forward issues and areas where we need to provide the Board with additional analysis and, in some cases, where we need to collect or analyze additional data to supplement the analyses and data that we presented.

---

[3] Fogg, G. E. 2003. *Influence of Paleosols on Fluid Flow and Transport: Perspective on Alluvial Complexity and Hydrogeology.* Presentation to the Nuclear Waste Technical Review Board Winter Meeting, January 28, 2003. Las Vegas, Nevada.

[4] Boyle, W. 2003. *Logic for Evaluating Engineered Barrier Performance.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC; Bodvarsson, G. May 13-14, 2003. *The Character of the Unsaturated Zone.* Washington, DC; Peters, M. 2003. *The Character of the In-Drift Environment.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC; Farmer, J. 2002. *Materials Performance.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC.

The DOE agrees that documentation of the evolution of the chemical environment on waste packages surfaces should contain a defensible technical basis that clearly states the assumptions and conclusions supporting the definition of the environment. The DOE is preparing or updating several Analysis and Modeling Reports that will collectively address our understanding of the evolution of the in-drift environment and the effect of that environment on waste package and drip shield surfaces. The long-term performance of a repository as analyzed using our current approach depends on the longevity of the waste package (especially since, in our view, conservative assumptions about the natural system diminish the relative projected effectiveness of the natural barriers). While the material selected for the outer barrier of the waste package is a very corrosion resistant alloy, environments can be created in the laboratory where this material undergoes unacceptable rates of corrosion. However, in our May presentations to the Board, we provided the Project's basis for concluding that these environments will not exist in the repository itself.

The DOE looks forward to the Board's reaction to our May presentations, but more importantly to the Board's insights and recommendations. We believe that more such integrated presentations, in which we can provide a more integrated picture of the fundamental basis for the efficacy of our design, should be planned for future Board meetings.

***We asked at the meeting whether a repository with lower peak temperatures of waste package surfaces would reduce the uncertainty, likelihood, or severity of corrosive solutions. However, the question was not answered directly. The Board believes that the Project should answer this question, and, if the answer is "Yes," a second question, "How much?" also should be answered. The technical basis for both answers should be documented carefully and completely in an AMR.***

**Response**:

The DOE agrees that maintaining below-boiling rock would reduce the uncertainties related to coupled processes.

However, as we discussed in our presentations[5] during the recent May Board meeting, we believe that a higher-temperature operating mode will lead to the drifts being drier for much longer, limiting aqueous phase corrosion due to seepage. We look forward to further interactions with the Board as we explain our data and models on this aspect in more detail, and obtain more in-depth Board review and comment on them.

The DOE has clearly indicated its intention to proceed to License Application with a design that retains the flexibility to be operated in a cooler mode should that be deemed necessary. Testing and analysis are ongoing to improve the technical basis for selecting postclosure thermal conditions. This experimental program and associated analyses will continue. As additional data and analyses are completed, the DOE will re-evaluate the technical basis for the choice of postclosure thermal conditions.

---

[5] Bodvarsson, G. 2003 (op. cit.); Peters, M. 2003. (op. cit.); Farmer, J. 2003 (op. cit.)

### *Materials studies*

*The Board was encouraged by the information presented on studies of corrosion in the presence of deliquescence, seepage, and $CaCl_2$ brines, but we note that many more studies, especially at elevated temperatures, will be needed to adequately explore potential corrosion mechanisms and corrosion rates in a high-temperature repository.*

**Response**:

The DOE agrees that additional studies are needed to adequately explore potential corrosion mechanisms in relevant repository environments more fully, particularly at the higher temperatures that will exist for a certain period of time in the repository's future evolution. As we discussed during our presentations[6] to the Board in the recent May meeting, the DOE is conducting tests in highly corrosive environments such as concentrated bulk calcium chloride environments (8 to 9 molar) with and without nitrate at temperatures above 120°C to characterize high-temperature corrosion processes. Initial results show that there is little margin between Alloy 22 corrosion potential and the critical potential for the initiation of localized corrosion. However, as noted during the January Board meeting[7], and again during the May meeting[8], calcium chloride brines are unstable in open systems and are unrealistic in a repository at Yucca Mountain. The ongoing materials testing program will continue to provide additional data to strengthen the technical basis for our understanding of corrosion mechanisms in relevant repository environments.

*The Board concurs with the observation of the Waste Package Materials Performance Peer Review Panel that the Project staff needs a senior-level, visionary leader with a strong background in materials science and engineering and with very good management credentials. Such a person could develop a systematic approach for identifying needed materials studies, ensure continuity of the effort, and enhance communication with the technical community.*

**Response**:

The observations of both the Board and the Panel on the value of a senior-level, visionary leader for the materials program are appreciated, and we are taking them seriously.

### *Prototype manufacturing*

*The Board is pleased that the DOE plans to procure waste package prototypes and develop welding processes. Programs in other countries that have undertaken prototyping activities have learned a great deal. In fact, some programs have encountered surprises that have taken considerable time to resolve. Manufacturing waste packages to the specifications required for*

[6] Farmer, J. 2003. (op cit.)

[7] Farmer, J. C. 2003. *Chemical Environment Evolution on Alloy 22.* Presentation at the Nuclear Waste Technical Review Board Winter Meeting, January 28, 2003. Las Vegas, Nevada.

[8] Peters, M. 2003. (op. cit.); Farmer, J. 2003. (op. cit.).

*a repository may require a significant development effort and corresponding lead-time before repository operations can begin. Information presented at the Board meeting did not contain detailed justification for the number of prototypes planned, but the Board concurs with the timing of the initial development effort. The Board strongly urges the DOE to begin prototype development as soon as possible.*

*As experience is gained, useful modifications of the waste package design may be identified. For example, the DOE may find that dual Alloy-22 lids may not be justified in light of the manufacturing complexity associated with a dual-lid design. The current plan not to stress-relieve or otherwise mitigate tensile stresses of the inner Alloy-22 closure weld also raises questions about the value of the dual-lid concept. Finally, because the trunnion-collar sleeves appear complex and their attachments to the waste package appear prone to crevice corrosion, there may be a need to reconsider these parts of the design during prototype manufacturing.*

**Response**:

The DOE recognizes the importance of waste package prototypes and has included prototypes as a fundamental part of the design, procurement, and fabrication strategy of the project. The DOE considers the manufacture of prototypes to be an integral part of the design process and recognizes the valuable information and knowledge that will come from a waste package prototype program. Accordingly, the DOE has planned and implemented a waste package prototype design, development, and fabrication program that started this year.

At this stage of the project, the DOE has planned for a total of fifteen waste package prototypes. These prototypes will be used in various ways:

- Several prototypes will be used to verify the closure processes and systems. The lids will be welded on the prototypes to verify the welding process, nondestructive examination processes, stress mitigation process, inerting process, leak detection process, robotic systems, and control systems, and to develop processes to repair closures that do not meet all requirements, as well as the integration of all these processes and systems.

- Several prototypes will be used for potential future destructive and non-destructive testing. Depending on the information required and requested, it is anticipated that these tests could include ring core tests, American Society of Testing Materials proof tests, drop tests, metallography, and others.

- Several prototypes will be used in the proposed training facility to demonstrate waste package handling processes.

- Prototypes will be necessary in the Operational Readiness Review process.

- Prototypes will be used in the training facility to train operators for Operational Readiness Review, start-up, and actual operations.

The manufacture of fifteen waste package prototypes will allow significant flexibility. Numerous combinations of the ten waste package configurations could be manufactured depending on the project needs. These fifteen prototypes will be manufactured over a 4 to 5 year

period starting in 2004, so determinations can be made in the future as to which configurations need to be manufactured. Furthermore, if a greater number of prototypes were necessary for any of the previously mentioned reasons (closure, training, etc.), it would be possible to manufacture several ¼ or ½ scale mockups, or even just the tops, instead of a single full-sized prototype for approximately the same cost.

The DOE agrees with the Board that, as design progresses and post-closure performance predictions evolve, it may be determined that the inner Alloy-22 lid will not be necessary. Because that determination has not yet been made, however, the first waste package prototype will include the inner Alloy-22 lid.

The DOE also agrees with the Board that the trunnion-collar sleeves may need to be reconsidered for various reasons. Fabrication of the first waste package prototype will provide valuable information that will allow decisions to be made regarding the trunnion-collar sleeves and, in fact, the trunnion-collar itself.

### *Repository System and Integration*

*Barrier performance - The Board is pleased that the DOE continues exploring ways to determine and display the contributions of individual barriers to performance of the overall repository system. The Board believes that such analyses can provide important insights into the respective roles of the different barriers. Furthermore, there appear to be opportunities for improving both the analytical approach for analyzing the performance of individual barriers and the clarity of the presentation of study results. The Board urges the DOE to continue this effort.*

**Response**:

The DOE agrees that analysis of the contribution of the natural and engineered barriers can provide important insights into repository performance and will continue to evaluate and improve the analytical approaches for analyzing the performance of individual barriers. As noted in our January letter to the Board[9], the barrier capability analyses may include evaluations of intermediate performance measures from the Total System Performance Assessment (TSPA) and pinch point analyses that report radionuclide mass flux or concentrations at selected interfaces between model components. These approaches to evaluating barrier capability are described in section 8.3 of the TSPA-LA Methods and Approach document[10]. These analyses will focus on the capabilities of these barriers to limit movement of water or radionuclides.

---

[9] Chu, Margaret, 2003. Letter to Michael L. Corradini responding to the views expressed by the Board on information presented in the September 2002 NWTRB meeting, with enclosure. January 24, 2003.

[10] BSC (Bechtel SAIC Company, LLC) 2002. Total System Performance Assessment-License Application Methods and Approach. TDR-WIS-PA-000006, Rev. 00, Las Vegas, Nevada; Bechtel SAIC Company, LLC.

*On-going scientific studies – As the Yucca Mountain project focuses on licensing activities, the temptation may be to divert resources from scientific studies to the licensing effort. The Board encourages the DOE to institute mechanisms that will ensure adequate funding and management commitments to on-going scientific studies.*

**Response:**

The DOE agrees that results of scientific studies will be valuable in increasing understanding of the potential behavior of the repository. To this end, DOE is planning additional scientific studies that will continue through the various stages of repository development, licensing, and operation as the project moves forward. This includes the Performance Confirmation program, which we expect will be the subject of a DOE presentation to the Board at a future meeting. The DOE has also initiated a Science and Technology Program with two objectives: 1) to improve existing and develop new technologies to achieve efficiencies, in terms of safety and savings, in the waste management system; and 2) to increase understanding of repository performance. An update on the Science and Technology program was presented at the May 2003 Board meeting. We look forward to continuing Board review as this new Program develops.

### *Waste Management System*

*With the approval of the site recommendation, the DOE's plans for operating the waste management system, including waste acceptance, transportation, and operations at a Yucca Mountain repository, have become extremely important. Since funding constraints in this area have caused plans to be deferred for several years, the Board is pleased to see that the DOE will resume work on the waste management system this year. The Board views this as a very important area and will hold additional meetings to review DOE plans in the coming months.*

**Response**:

The DOE agrees that work on the waste management system is important and will be pleased to support future meetings with the Board to review DOE plans in this area.

*The Board recommends that the transportation planning and development effort adopt a "systems" approach, addressing both strategic and operational considerations. The Board views the early involvement of external stakeholders as critical to developing a comprehensive plan for the waste management system and to building public confidence in those plans. Because proactive engagement of external stakeholders is a time-consuming process, the Board encourages the DOE to initiate this activity as soon as possible.*

**Response:**

The DOE agrees with the Board's recommendation that transportation planning and development should use a systems approach for both strategic and operational concerns to ensure that the transportation system and its operation are safe, secure, and reliable. As we noted in the

February Panel meeting on the Waste Management System[11], the DOE is committed to an institutional process that includes working closely with states, tribes, and local governments affected by the transportation of Spent Nuclear Fuel and high-level waste to Yucca Mountain. The DOE will build on previous cooperative planning experience, such as our experience at the Waste Isolation Pilot Plant, in developing its transportation plan.

[11] Williams, J. 2003. *Developing a successful transportation program.* Presentation at the Nuclear Waste Technical Review Board Panel Meeting on the Waste Management System, February 25, 2003. Las Vegas, Nevada.

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

April 30, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the U.S. Nuclear Waste Technical Review Board, I want to thank your staff for participating in the February 25, 2003, meeting of the Board's Panel on the Waste Management System in Las Vegas, Nevada. We found the presentations very clear and helpful in carrying out the Board's evaluation of the technical and scientific validity of activities undertaken by the Secretary of Energy related to managing the disposal of the nation's spent nuclear fuel and high-level radioactive waste.

A major purpose of the meeting was to familiarize the Panel members with the baseline from which DOE work will progress in the years ahead. We think that goal was achieved. The presentations at the meeting make clear that a sustained and well-thought-out effort will be needed to develop a transportation program that will engender public confidence. Other observations and recommendations drawn from the information presented at the meeting are summarized below.

**Transportation and Waste Acceptance**

In the Board's view, the DOE should adopt safety as a guiding principle in planning and developing a transportation system and should develop an integrated safety plan for guiding the development process. The schedule for such transportation planning also is important, and it appears that the DOE's current timetable may be optimistic, considering the substantial amount of work to be done. For example, the DOE presentation identified a transportation strategic plan, to be issued in fiscal year 2003; a transportation project management plan, to be developed during fiscal year 2003; and transportation operations plans, to be developed in fiscal year 2005 and beyond. As the highest-level document, the strategic plan is clearly the most urgent, and public involvement in its development is essential. The Board recommends that the DOE publish a draft strategic plan for public comment as soon as practical.

During the afternoon session, several representatives of affected local governments made excellent presentations on potential issues of concern related to the transportation of spent nuclear fuel through their areas. These presentations and the comments of members of the public made clear that affected parties would like to know as soon as possible what modes and routes will be used for transporting spent nuclear fuel to a Yucca Mountain repository so that they can

begin their own preparations. The Board also is interested in this information and requests that the DOE provide its timeline for making those decisions and for issuing the "Record of Decision" for the Yucca Mountain final environmental impact statement.

The DOE presentation indicated that, because of pending lawsuits, there are few, if any, on-going interactions on waste acceptance between the DOE and electric utilities. However, it is apparent that significant coordination is needed for the waste acceptance process to be smooth and efficient. For example, no casks have been certified for transporting some of the higher-burnup spent fuel likely to be generated in the future. Coordination of cask development (and certification) with utility shipping needs and with repository and transportation-system capabilities will be important for efficient operations. The DOE should seek approaches to improving communication with utilities in a way that will facilitate planning for the waste acceptance process.

**Surface and Underground Facilities**

The Board would appreciate receiving additional information on two significant issues related to the design and operation of surface and underground facilities. First is the possibility that a small amount of spent fuel will be damaged during transportation to Yucca Mountain. Spent fuel found to be damaged when the casks are opened at the surface facilities will be handled in the remediation building. However, DOE does not plan to have the remediation building operational until three years after the receipt of spent fuel begins. The Board requests more information about the DOE's plans for resealing and storing damaged spent fuel during the interim period before construction of the remediation building. Second, the DOE presentation identified two potentially significant changes in the design and operation of the underground facilities: (1) use of a wheeled waste transporter and (2) location of exhaust drifts and shafts. The Board would like more details on the technical bases for these concepts.

Again, thank you for the DOE's support of this meeting. Waste acceptance and transportation are likely to become topics of significant interest in the months ahead, and the Panel on the Waste Management System anticipates holding additional meetings to review the DOE's progress in this area.

Sincerely,

{Signed by}

Michael L. Corradini
Chairman

**Department of Energy**
Washington, DC 20585

July 22, 2003

Dr. Michael L. Corradini
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, Virginia 22201-3367

Dear Dr. Corradini:

Thank you for your April 30, 2003, letter expressing the Nuclear Waste Technical Review Board's (Board) perspective on our February 25, 2003 meeting.

The Department of Energy appreciates and values the Board's continuing review of our activities as we proceed toward submitting a license application for a repository construction authorization to the Nuclear Regulatory Commission. Our responses to the views expressed by the Board are presented in the enclosed letter.

The Department has benefited from the constructive views of the Board and we look forward to continuing our dialogue.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
*Responses to the April 30, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board*

Michael L. Corradini, Ph.D -2-

bcc w/encl:
L.J. Desell, DOE/HQ (RW-1), FORS
T.E. Kiess, DOE/HQ (RW-40E), FORS
Richard Goffic, BAII, Washington, DC
J.T. Mitchell, Jr., BSC, Las Vegas, NV
J.N. Bailey, BSC, Las Vegas, NV
CMS Coordinator, BSC, Las Vegas, NV
M.W. Pendleton, BSC, Las Vegas, NV
N.H. Williams, BSC, Las Vegas, NV
W.J. Boyle, DOE/ORD (RW-40W), Las Vegas, NV
A.V. Gil, DOE/ORD (RW-40W), Las Vegas, NV
C.M. Newbury, DOE/ORD (RW-40W), Las Vegas, NV
J.D. Ziegler, DOE/ORD (RDW-40W), Las Vegas, NV
Records Processing Center – "12"

**Responses to the April 30, 2003 letter to DOE from the Nuclear Waste Technical Review Board**

***Transportation***

*In the Board's view, the DOE should adopt safety as a guiding principle in planning and developing a transportation system and should develop an integrated safety plan for guiding the development process. The schedule for such transportation planning also is important, and it appears that the DOE's current timetable may be optimistic, considering the substantial amount of work to be done.*

**Response:** DOE agrees that safety should be a guiding principle in planning and developing a transportation system for shipments to a geologic repository in Nevada. We also agree that an integrated safety plan is necessary to guide the development process. Consequently, DOE looks forward to further discussions with the Board regarding the format and content of such a plan. DOE also agrees that the public should be involved in the development of the Transportation Strategic Plan and, therefore, plans to seek stakeholder input at the July 16-17, 2003 Transportation External Coordination Working Group meeting. Input received during that meeting will be addressed as DOE finalizes its Plan.

***Waste Acceptance***

*..it is apparent that significant coordination is needed for the waste acceptance process to be smooth and efficient. For example, no casks have been certified for transporting some of the high burn-up spent fuel likely to be generated in the future. Coordination of cask development (and certification) with utility shipping needs and with repository and transportation systems capabilities will be important for efficient operations. The DOE should seek approaches to improving communications with utilities in a way that will facilitate planning for the waste acceptance process.*

**Response:** DOE acknowledges that commercial utilities are producing higher burn-up spent fuel than was envisioned when the Standard Contract was signed. Recognizing this future scenario, DOE has considered and incorporated repository facility design features and operational scenarios to receive, package, and emplace higher burn-up spent fuel as a part of DOE's ongoing design evolution process. For example, repository surface facilities are being designed to blend spent nuclear fuel in waste packages with a combination of high burn-up spent fuel and cooler older spent fuel to manage thermal loading requirements.

Development and certification of transportation cask designs for higher burn-up commercial spent nuclear fuel is a multi-faceted endeavor requiring close regulatory interactions with the Nuclear Regulatory Commission, transportation cask design and production assessments of cask vendors, and logistical coordination with commercial nuclear utilities. DOE is examining how best to develop and manage a transportation system that would accommodate the variety and range of spent nuclear fuel that would be available for shipment to support repository operations. However, the submittal of a license application for repository construction authorization continues to be our primary program focus, especially given the exigencies of the budget process. DOE has requested funding in fiscal year 2004, and will

continue to do so in future budget requests to examine high burn-up spent nuclear fuel and other transportation and waste acceptance issues

***Surface and Underground Facilities***

*The Board would appreciate receiving additional information on two significant issues related to the design and operation of surface and underground facilities. First is the possibility that a small amount of spent fuel will be damaged during transportation to Yucca Mountain. Spent fuel found to be damaged when the casks are opened at the surface facilities will be handed in the remediation building. However, DOE does not plan to have the remediation building operational until three years after the receipt of spent nuclear fuel begins.*

**Response:** DOE's design process is evolutionary, and will continue to be refined and optimized. The design and operational concepts presented last February were provided to the Board as a snapshot in time. DOE realizes that specific design feature details, including the handling of off-normal operations, must be addressed in a license application. The sequencing of the functional status of the Remediation Building shown to the Board was primarily based on expected funding profiles and how construction could be adjusted to meet the expected funding scenarios. Options are now being developed to construct the remediation capabilities first and have them built into the main Dry Transfer Building instead of as a stand alone separate building. Damaged SNF could also be stored after receipt until the necessary remediation facilities are completed so as not to disrupt any proposed shipping scenarios. DOE and our M&O contractor have recently awarded a contract to enlist the services of a surface facility design contractor. Remediation capability is a major part of this present design effort.

*..the DOE presentation identified two potentially significant changes in the design and operation of the underground facilities: (1) use of a wheeled waste transporter and (2) location of exhaust drifts and shafts. The board would like more details on the technical bases for these concepts.*

**Response:** Since the February 2003 meeting, DOE has reexamined the utility of the "wheeled waste transporter." Based on a review of how the "wheeled waste transporter" would operate within the subsurface tunnel environment, DOE and the M&O have decided to pursue a conceptual design with a rail based transporter. Consistent with the evolution of the surface design approach, DOE is pursuing a modular subsurface construction approach - building underground panels of emplacement drifts in phases. Consequently, exhaust drifts and exhaust shafts will be constructed to best accommodate the sequential construction of the emplacement panels. DOE expects to have a greater fidelity of detail regarding this and other design issues as the design stabilization efforts mature.

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

June 27, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On February 24, 2003, the Nuclear Waste Technical Review Board's (Board) Panel on the Natural System and Panel on the Engineered System held a joint meeting in Las Vegas devoted to seismic issues. As indicated in the March 10, 2003, letter sent to you by William Barnard, it was a very informative and successful meeting. This was due in large part to the Department of Energy's (DOE) efforts and its willingness to discuss difficult topics where much of the information is preliminary and final positions have not yet been established. Reports by Board consultants who attended the meeting can be found on the Board's web site.

The DOE and its contractors, the U.S. Geological Survey, the U.S. Bureau of Reclamation, the University of Nevada at Reno (UNR), and others set a high standard in the basic geological and seismological studies on which seismic hazard at Yucca Mountain was evaluated. This information was incorporated in a state-of-the-art probabilistic seismic hazard analysis (PSHA) completed in 1998. The Board's assessment of the application of the PSHA to preclosure (approximately the first 100 years) and postclosure (the first 10,000 years) is based on the results that were available at the time of our February meeting. A basic concern of the Board is that although the PSHA is, in general, sound, extending it to very low probabilities results in ground-motion estimates about which there are serious technical questions. These relate to the lack of physical realism and the implications of these unrealistic estimates for performance assessment, design, and scientific confidence. Following is the Board's evaluation of the material presented, its strengths and weaknesses, and specific recommendations to the DOE on seismic issues.

**Preclosure Ground Motions**

With respect to preclosure, the ground motions proposed for design at annual probabilities of exceedance (APE) of $10^{-3}$ to $10^{-4}$ appear reasonable. However, as Bechtel SAIC (BSC) consultant Robert Kennedy stated, an evaluation to see if the surface facilities meet performance goals for critical systems, structures, and components could require using ground motions whose APE is as low as $10^{-6}$. If physically unrealistic, as may be the case (as discussed below), such motions could pose an undue burden on the design and operation of these facilities.

**Postclosure Ground Motions**

In the Board's view, the very-low-probability (APEs of $10^{-6}$ to $10^{-8}$) ground motions proposed for use in postclosure performance assessment are generally unrealistic, physically unrealizable, or outside the limits of existing worldwide seismic records or experience, particularly when Yucca Mountain source and site conditions are taken into account. These ground motions can require unrealistic source characteristics (e.g., stress drops) and unrealistic strains, which may exceed the ability of the rock to sustain without fracturing. For example, some of the real earthquake ground-motion recordings used in the consequence analysis for performance assessment are scaled up (increased) by factors higher than 100 to reach the "target" level of ground motions (e.g., 535 cm/sec peak ground velocity at an APE of $10^{-7}$), which themselves are based on extending the results from the PSHA and modifying them to take into account local site conditions. In some cases, this method of scaling yielded peak ground accelerations and velocities (e.g., 20 g peak ground acceleration and 1790 cm/sec peak ground velocity) well above already unrealistic target levels. Many DOE and BSC presenters at the meeting shared many of these same views. However, as discussed later in this letter, differences of opinion may exist between the Board and the DOE on how to proceed, given this lack of physical realism.

The very-low-probability ground motions need to be bounded on the basis of sound physical principles. The DOE indicated that it is carrying out such studies (e.g., limitations posed by source conditions and local site conditions). The studies will be challenging. Aside from an ongoing study in Switzerland, we are not aware of other recent systematic attempts to place physical bounds on earthquake ground motion. Despite these difficulties, the Board strongly recommends that the DOE complete these studies, subject them to external peer review, and implement them accordingly to limit the proposed very-low-probability ground motions.

The DOE also should evaluate and consider the work being carried out by Dr. James Brune and his colleagues at UNR as an alternative line of evidence for limiting ground motions. The evaluation of precarious rocks and other formations at Yucca Mountain suggests that during the last 10,000,000 years, ground motions that have occurred at Yucca Mountain may be substantially less than those estimated by the PSHA. Dr. Brune attributes this to the incorrect handling of uncertainty in the PSHA and other seismic hazard analyses.

The Board notes two additional areas where lack of data may affect the magnitude of the estimated ground motions: insufficient geotechnical data on the Topopah Springs Lower Lithophysal unit (Tptpll), which constitutes some 80 per cent of the emplacement rock in the proposed repository and shear modulus data at strains larger than 0.1 per cent, the range of strains induced by the proposed very-low-probability ground motions.

## Drift Degradation and Other Topics

The Yucca Mountain Project has made excellent progress in assessing underground opening stability and drift degradation due to both seismic and thermal processes. Models used to predict tunnel behavior need to be calibrated against the conditions expected in the repository (e.g., information obtained from the ESF and, in particular, the cross drift). Models used to predict tunnel performance under extreme dynamic loading should be compared to nuclear test damage data and rockburst damage observed in mines with comparable rock-mass conditions. Analyses also need to account for long-term behavior (e.g., static fatigue) using representative rock-mass properties to simulate raveling and spalling processes expected during preclosure and postclosure periods. Particular attention should be focused on rock properties and analytical models to understand brittle failure and to predict the outcome of the failure process for this heterogeneous rock mass with its spatial and temporal variability in properties.

Recent studies of brittle failure in heterogeneous rocks near excavations have shown that conventional linear or curved failure criteria may not be appropriate for the Tptpll unit. The Board recommends that models be adopted and developed that can properly simulate the strain-dependent tensile spalling mechanism clearly observed in the cross drift and that drift design be based on such failure criteria. If tunnel openings have the potential to collapse, raveling and failure processes will continue until rock mass bulking substantially fills the drift. During this process, dynamic forces and nonsymmetrical rock pressures will develop on the drip shield. The potential for drip shield deformation and corrosion under these conditions needs to be analyzed.

If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of seismic activity, such modifications need to be evaluated in terms of their overall impact upon repository operations and performance.

## Implications of Highly Conservative Assumptions

A number of highly conservative assumptions have been used in addressing seismic issues. The DOE may find conservatism attractive because it could provide a way to show regulatory compliance in the face of uncertainty. As stated above, DOE and BSC scientists agree that many of their estimates are highly conservative or physically unrealistic. The DOE maintains, however, that this is not necessarily a problem because the assumptions are consistently conservative and the repository system will still show regulatory compliance. It appears that the DOE intends to use the ground-motion bounding studies as evidence of conservatism rather than as a means of modifying the ground motion estimates themselves. Not all the assumptions in the Project's analysis of this complex, highly coupled system have been fully assessed, e.g., the effects of seismically and thermally induced drift degradation on seepage and local flow and transport, and consideration of seismically induced waste package failure modes not related to stress-corrosion cracking. These assumptions need to be evaluated. If they are important, the assumed level of conservatism could be affected.

The Board recommends that the DOE not take a physically unrealistic or highly conservative approach for several reasons: (a) High levels of conservativism can lead to a skewed understanding of repository behavior and the significance of different events; (b) High levels of conservatism can introduce consideration of events for which there is little or no understanding or engineering experience; (c) Compounding conservative assumptions does not always produce conservative results, e.g., the worst case for drift stability is not when the horizontal and vertical stresses are both very high; (d) High levels of conservatism may lead to unreasonably high costs and may have a serious effect on the eventual development of both surface and subsurface designs; (e) If conservatism stems from a lack of understanding, it tends to undermine confidence in the scientific basis of the process under consideration. Physically unrealistic results, inappropriately extrapolated from physically realistic databases and analyses, could cast unwarranted doubt on much of the truly excellent work carried out in this area; (f) Finally, if "unacceptable" consequences are discovered later, it may be more difficult to justify subsequent reductions of elevated ground-motion estimates previously assumed to be acceptable.

The Board thanks you and the DOE staff and contractors for the effort extended in making the meeting as successful as it was.

Sincerely,

Michael L. Corradini
Chairman

**Department of Energy**
Washington, DC 20585
October 8, 2003

Dr. Michael L. Corradini, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of June 27, 2003, providing the Nuclear Waste Technical Review Board's (Board) perspective on information presented by the U.S. Department of Energy (Department) on seismic issues at the joint meeting of the Board's Natural System and Engineered System Panels in February 2003.

The Department appreciates the Board's continuing review of our activities as we develop the license application for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board and we look forward to further dialogue on seismic issues.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
*Responses to the Nuclear Waste Technical Review Board Comments on U.S. Department of Energy Presentations Given at the February 2003 Joint Natural System and Engineered System Panel Meeting on Seismic Issues*

Michael L. Corradini, Ph.D. -2-

bcc w/encl:
T. E. Kiess, DOE/HQ (RW-40E), FORS
Richard Goffi, BAH, Washington, DC
J. T. Mitchell, Jr., BSC, Las Vegas, NV
J. N. Bailey, BSC, Las Vegas, NV
CMS Coordinator, BSC, Las Vegas, NV
M. W. Pendleton, BSC, Las Vegas, NV
N. H. Williams, BSC, Las Vegas, NV
J. P. Ake, USBR, Las Vegas, NV
W. J. Arthur, III, DOE/ORD (RW-2W), Las Vegas, NV
J. R. Dyer, DOE/ORD (RW-2W), Las Vegas, NV
W. J. Boyle, DOE/ORD (RW-40W), Las Vegas, NV
A. V. Gil, DOE/ORD (RW-40W), Las Vegas, NV
V. F. Iorii, DOE/ORD (RW-40W), Las Vegas, NV
C. M. Newbury, DOE/ORD (RW-40W), Las Vegas, NV
S. P. Rives, DOE/ORD (RW-2W), Las Vegas, NV
P. F. Sanchez-Bartz, DOE/ORD (RW-2W), Las Vegas, NV
J. D. Ziegler, DOE/ORD (RW-40W), Las Vegas, NV
Mark Peters, BSC, Washington, DC
Bob Budnitz, LLNL, Washington, DC
Records Processing Center – "11"

MFR:OLA&S:CMN-1812

**Responses to the Nuclear Waste Technical Review Board Comments on U.S. Department of Energy (DOE) Presentations given at the February 2003 Joint Natural System and Engineered System Panel Meeting on Seismic Issues**

***Preclosure Ground Motions***

*With respect to preclosure, the ground motions proposed for design at annual probabilities of exceedance (APE) of $10^{-3}$ to $10^{-4}$ appear reasonable. However, as Bechtel SAIC (BSC) consultant Robert Kennedy stated, an evaluation to see if the surface facilities meet performance goals for critical systems, structures, and components could require using ground motions whose APE is as low as $10^{-6}$. If physically unrealistic, as may be the case (as discussed below), such motions could pose an undue burden on the design and operation of these facilities.*

**Response:**

10 CFR Part 63.102[1] only requires consideration of initiating events that are reasonable, i.e., based on the characteristics of the geologic setting and the human environment and consistent with precedents adopted for nuclear facilities with comparable or higher risks to workers and the public. Given this requirement, the DOE plans to evaluate seismically initiated event sequences for preclosure safety analyses for earthquake ground motions with APEs of $10^{-4}$ and greater.

***Postclosure Ground Motions***

*In the Board's view, the very-low-probability (APEs of $10^{-6}$ to $10^{-8}$) ground motions proposed for the use in postclosure performance assessment are generally unrealistic, physically unrealizable, or outside the limits of existing worldwide seismic records or experience. . . . Many DOE and BSC presenters at the meeting shared many of these views. However, as discussed later in this letter, differences of opinion may exist between the Board and DOE on how to proceed, given this lack of physical realism.*

---

[1] 66 FR 55732. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final Rule 10 CFR Part 63.

*The very-low-probability ground motions need to be bounded on the basis of sound physical principles. The DOE indicated that it is carrying out such studies (e.g., limitations posed by source conditions and local site conditions). The studies will be challenging. Aside from an ongoing study in Switzerland, we are not aware of other recent systematic attempts to place physical bounds on earthquake ground motions.*

*Despite these difficulties, the Board strongly recommends that the DOE complete these studies, subject them to external peer review, and implement them accordingly to limit the proposed very-low-probability ground motions.*

**Response**:

As the Board notes, the DOE is conducting studies to bound the very-low probability ground motions. While the results may not be available in time to provide direct input to Total System Performance Assessment for the License Application (TSPA-LA), they will be available after independent technical review to support the U.S. Nuclear Regulatory Commission staff's review of the LA and provide clarification regarding the level of conservatism in the LA.

*The DOE also should evaluate and consider the work being carried out by Dr. James Brune and his colleagues at University of Nevada at Reno (UNR) as an alternative line of evidence for limiting ground motions. The evaluation of precarious rocks and other formations at Yucca Mountain suggests that during the last 10,000,000 years, ground motions that have occurred at Yucca Mountain may have been substantially less than those estimated by the Probabilistic Seismic Hazard Analysis (PSHA). Dr. Brune attributes this to the incorrect handling of uncertainty in the PSHA and other seismic hazard analyses.*

**Response**:

The DOE agrees and is considering Dr. Brune's observations as an alternative line of evidence for limiting ground motions. His observation that there is no shattered rock at Yucca Mountain as would be expected if there had been extreme ground motion during the last 13 million years is the basis for one of the ongoing studies to bound the very-low probability ground motions. Specifically, a strain threshold at which rock failure would be expected is being identified from consideration of measured rock properties. The strain threshold is then being used to establish an upper limit on ground motions that have occurred in the last 13 million years (the approximate age of the tuff units). The results of these studies may be included as *a priori* information in the development of updated ground motion distributions.

The DOE is currently negotiating with Dr. Brune and his associates at UNR to continue their studies of near-surface attenuation (kappa) and possibly conduct finite-source ground motion calculations to investigate possible limiting effects on the very low-probability ($10^{-6}$ and less) ground motions of physically bounded source parameters.

*The Board notes two additional areas where lack of data may affect the magnitude of the estimated ground motions: insufficient geotechnical data on the Topopah Spring Lower Lithophysal unit (Tptpll), which constitutes some 80 per cent of the emplacement rock in the proposed repository and shear modulus data at strains larger than 0.1 per cent, the range of strains induced by the proposed very-low probability ground motions.*

**Response**:

The ongoing studies to bound the very-low probability ground motions are also addressing high-strain shear-modulus reduction and damping. Specifically, high-strain properties for the volcanic tuff below the repository horizon are being developed by nonlinear numerical modeling. These properties will then be input to the site response model to generate "saturated" ground motions at the repository waste-emplacement level. While the results may not be available in time to provide direct input to Total System Performance Assessment for the License Application (TSPA-LA), they will be available after independent technical review to support the U.S. Nuclear Regulatory Commission staff's review of the LA and provide clarification regarding the level of conservatism in the LA.

***Drift Degradation and other topics***

*Models used to predict tunnel behavior need to be calibrated against the conditions expected in the repository (e.g., information obtained from the Exploratory Studies Facility and, in particular, the cross drift). Models used to predict tunnel performance under extreme dynamic loading should be compared to nuclear test damage data and rock burst damage observed in mines with comparable rock-mass conditions. Analyses also need to account for long-term behavior (e.g., static fatigue) using representative rock-mass properties to simulate raveling and spalling processes expected during preclosure and postclosure periods. Particular attention should be focused on rock properties and analytical models to understand brittle failure and to predict the outcome of the failure process for this heterogeneous rock mass with its spatial and temporal variability in properties.*

**Response:**

The short time available for presentation at the Seismic Panel Meeting unfortunately did not allow for a detailed review of all the geomechanical studies that have been performed and are now underway that address some of the issues brought out in this comment. During the process of validation of the numerical modeling techniques used for the drift degradation models, comparison was made to the observed sidewall fracturing in the Enhanced Characterization of the Repository Block lithophysal units. Comparison was also made between the small number of observed wedge-type failures in non-lithophysal units to the model predictions. Details of the validation can be found in BSC (2003)[2].

The 3-Dimensional Distinct Element Code (3DEC) and Universal Distinct Element Code (UDEC) models used for the dynamic stability analyses have been extensively validated in other projects. The validation was against field data from high explosive testing (for the Defense Nuclear Agency) and against damage from rockbursts in deep mines (by numerous authors in the United States, Canada, and South Africa). An example of a validation exercise involving detailed comparison of the ability of a number of continuum and discontinuum numerical models (including UDEC) to simulate supported tunnels in fractured rocks can be found in Senseny (1993)[3]. We have not explicitly compared the models here to nuclear tests at the Nevada Test Site, but this would be a good confidence-building exercise, with the caveat that the characteristics of the incoming waveforms are significantly different between explosions and earthquakes, with resulting potential difference in damage mechanisms.

The project is currently addressing the issue of time-dependent rock mass degradation via a combined laboratory testing and numerical modeling program. We are conducting static fatigue measurements on tuff core samples to better understand the relationship of "time to failure" as a function of stress level. To understand the impact of lithophysal porosity, the DOE is:

1) calibrating the Particle Flow Code (PFC) model against the laboratory data to establish its ability to reproduce the basic static fatigue response of non-lithophysal tuff;

---

[2] BSC (2003). *Drift Degradation Analysis*, ANL-EBS-MD-000027, Rev. 02. Las Vegas, Nevada: Bechtel SAIC Company.

[3] Senseny, P.E. 1993. "Stress Wave Loading of a Tunnel: A Benchmark Study." *Proceedings of the Symposium – Dynamic Analysis and Design Considerations for High-Level Nuclear Waste Repositories, San Francisco, California, August, 19-20, 1992*. Hossain, Q.A., ed. Pages 311-338. New York, New York: American Society of Civil Engineers.

2) investigating the impact of lithophysal voids numerically by adding porosity to the calibrated numerical rock samples, and conducting simulated static fatigue experiments to derive lithophysal time to failure plots; and

3) incorporating this logic into previously validated tunnel scale models for investigation of time-related degradation under in situ and thermal loading. The PFC model is used here to predict brittle fracturing modes of the solid matrix between lithophysae. The primary heterogeneities examined here are the lithophysae and their variability in size, shape and porosity. This work will be completed in Fiscal Year 2004.

*Recent studies of brittle failure in heterogeneous rocks near excavations have shown that conventional linear or curved failure criteria may not be appropriate for the Tptpll unit. The Board recommends that models be adopted and developed that can properly simulate the strain-dependent tensile spalling mechanism clearly observed in the cross drift and that drift design be based on such failure criteria. If tunnel openings have the potential to collapse, raveling and failure processes will continue until rock mass bulking substantially fills the drift. During this process, dynamic forces and nonsymmetrical rock pressures will develop on the drip shield. The potential for drip shield deformation and corrosion under these conditions needs to be analyzed.*

**Response**:

This comment goes to the heart of modeling of brittle rock behavior. The project is currently using the PFC program (using parallel bonds for particles) to model and understand the brittle fracturing response of lithophysal rock. The DOE has performed extensive calibration of the model against laboratory testing of large lithophysal samples and their failure mechanisms. The PFC model provides a reasonable prediction and representation of tensile fracturing during axial splitting failure of the laboratory samples. The basic failure mechanism in compression for lithophysal rock, shown by the PFC model, is tensile fracturing between lithophysae, which subsequently coalesce as the sample macroscopically yields. This process is porosity dependent, leading to reduction of strength and modulus as the lithophysal porosity increases.

The PFC model has been shown to successfully reproduce the relationship of uniaxial compressive strength to lithophysal porosity as shown in the laboratory. It appears that the model adequately represents the small-scale mechanism of tensile failure between lithophysae, leading to the larger sample-scale failure mechanisms at the laboratory and field scale. Because it is computationally difficult to examine tunnel-scale problems with PFC, the basic failure response

defined by the laboratory and field testing and supplemented by PFC has been encapsulated into the UDEC program that is used to represent tunnel-scale degradation processes. The UDEC program has been calibrated to produce an equivalent mechanical constitutive model to the PFC model and is verified by comparison to laboratory data and observations of damage in the Enhanced Characterization of the Repository Block. UDEC, which is a discontinuum model, is used to predict the tunnel degradation process, including the raveling and bulking process. The model has been used to examine drip shield static and dynamic loadings that are generally non-symmetric in nature. The load distributions on the drip shield have been supplied to the drip shield structural designers who are using them to estimate stresses and deformations.

*If, after considering the consequences and the risks to the public, the DOE decides to modify the repository design to mitigate the effects of seismic activity, such modifications need to be evaluated in terms of their overall impact upon repository operations and performance.*

**Response**:

The DOE does not expect modifications to the repository design will be required to mitigate the consequences of high-amplitude, low-probability ground motions. Even using the present, probably unrealizable ground motion estimates, it appears that the calculated consequences will be acceptable. Any proposed changes to repository design to mitigate the potential effects of seismic activity will be processed through our design control procedures to evaluate the overall impact on repository operations and performance.

***Implications of highly conservative assumptions***

*A number of highly conservative assumptions have been used in addressing seismic issues. It appears that the DOE intends to use the ground-motion bounding studies as evidence of conservatism rather than a means of modifying the ground motion estimates themselves. Not all the assumptions in the Project's analysis of this complex, highly coupled system have been fully assessed, e.g., the effects of seismically and thermally induced drift degradation on seepage and local flow and transport, and consideration of seismically induced waste package failure modes not related to stress-corrosion. These assumptions need to be evaluated. If they are important, the assumed level of conservatism could be affected.*

*The Board recommends that the DOE not take a physically unrealistic or highly conservative approach for several reasons: (a) High levels of conservatism can*

*lead to a skewed understanding of repository behavior and the significance of different events; (b) High levels of conservatism can introduce consideration of events for which there is little or no understanding or engineering experience; (c) Compounding conservative assumptions does not always produce conservative results, e.g., the worst case for drift stability is not when the horizontal and vertical stresses are both very high; (d) High levels of conservatism may lead to unreasonably high costs and may have a serious effect on the eventual development of both surface and subsurface designs; (e) If conservatism stems from a lack of understanding, it tends to undermine confidence in the scientific basis of the process under consideration. Physically unrealistic results, inappropriately extrapolated from physically realistic databases and analyses, could cast unwarranted doubt on much of the truly excellent work carried out in this area; (f) Finally, if "unacceptable" consequences are discovered later, it may be more difficult to justify subsequent reductions of elevated ground-motion estimates previously assumed to be acceptable.*

**Response:**

The DOE agrees with the Board that the seismic ground motions that we will be using in the LA corresponding to the very lowest annual probabilities of exceedence (APEs of $10^{-6}$ and below) are highly conservative and may indeed be "physically unrealizable". However, despite the various issues with using these probably conservative values, the DOE considers that using them is acceptable in the TSPA that will support the LA. To address the problems associated with using such ground motions, we are now carrying out several different studies to bound the very low-probability ground motions; whose ultimate objective is to provide a technical basis for a more realistic set of ground motions in the very-low-APE range.

The DOE agrees with all of the reasons cited by the Board as to why taking a physically unrealistic or highly conservative approach is not desirable. We are working to assure ourselves that none of the potential problems cited by the Board will actually occur for the case of the highly conservative extreme seismic ground motions that we will be using in the LA. Most importantly, we are taking care to assure that using these conservative values will actually produce conservative results throughout.

Also, we agree with the Board's concern that using these values can produce a skewed understanding of actual behavior. We have performed various analyses of the system response at what we believe are more realistic ground-motion levels, and we will be performing more such analyses in the future. Furthermore, we are very sensitive to the possibility that using the unrealistically high ground-motions

may "cast unwarranted doubt on much of the truly excellent work carried out in this [seismic] area" (quoting from the Board's letter). We will therefore take care, as we develop the text supporting this aspect of our LA, to explain how to interpret the analysis results appropriately, and why possible misinterpretations are not correct.

The implications of unrealistically high seismic ground motions as inputs to the design of both the surface facilities and the underground facilities are important to DOE. This includes not only the implications for the physical designs themselves but also the cost implications. This is one reason why we are pursuing the work to bound the very-low probability ground motions. Another reason is the important implications of these extreme ground motions on drift degradation, on seepage and in-drift transport, and on possible seismic-induced failures of the waste-packages. While the results may not be available in time to provide direct input to Total System Performance Assessment for the License Application (TSPA-LA), they will be available after independent technical review to support the U.S. Nuclear Regulatory Commission staff's review of the LA and provide clarification regarding the level of conservatism in the LA.

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

June 30, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board thanks you and the rest of the Yucca Mountain Project team for participating in the Nuclear Waste Technical Review Board's May 2003 meeting in Washington, D.C. The meeting was extremely productive and informative. The first day's presentations were comprehensive, well integrated, and thought-provoking; the two large charts were especially useful integrating tools. The Board valued the extended question-and-answer periods, which allowed presenters to explain thoroughly the rationale for their conclusions. The extra effort that went into preparing these presentations was evident and, in the Board's view, worthwhile. The Board also found interesting the insights provided by you and your deputy director, John Arthur, particularly the comments related to the management challenges facing the civilian radioactive waste management program.

In this letter, the Board provides some initial reactions to the Project's technical presentations at the May meeting. The letter also conveys the Board's views on the *Final Report* of the Igneous Consequences Peer Review Panel. Last, the letter offers the Board's thoughts on the natural analogue studies being conducted by the DOE at Peña Blanca.

**Initial Board Reactions to Presentations by the Project at the May Board Meeting**

The Board continues to believe that the concept of a "safety case," which is endorsed strongly by virtually all the major nuclear waste management programs abroad, has considerable merit. In fact, during the meeting, Project scientists were able to verbalize why they believe that a Yucca Mountain repository would isolate and contain waste effectively. An updated written narrative description similar to those oral comments would make the Project's approach to ensuring safety more transparent and understandable.

The first day of the meeting was structured to allow the Project to describe the thermal aspects of the current repository design and operating mode, how the thermal aspects have been analyzed, and the results of those analyses. In response, the Project delivered three major presentations related to in-drift thermohydrology, in-drift thermohydrochemistry, and Alloy-22

corrosion. The subjects presented are critical for predicting the potential repository's overall performance. Other factors relevant to performance, such as drift degradation and the thermal properties of the lower lithophysal unit, however, were not addressed fully. The Board's initial reaction is that potentially significant questions remain about the technical basis for the Project's thermal analyses. These questions include concerns about the initiation of localized corrosion and the technical basis underlying Project claims about capillary and vaporization barriers. The Board is in the process of carefully evaluating the DOE's presentations from the May Board meeting and will be preparing more detailed comments for the DOE on these subjects.

The Board is pleased that the Project is committed to sponsoring long-term research on "outside of the box" scientific and technical issues. It is not yet clear, however, how data and analyses from the Science and Technology Program will be integrated into the license application process or the performance confirmation effort mandated by the Nuclear Regulatory Commission.

## Board Views on *Final Report* of Igneous Consequences Peer Review Panel

At the May meeting, a member of the Igneous Consequences Peer Review Panel (Panel) presented the Panel's findings from its *Final Report*. In the Board's view, the Panel has made an important contribution to the assessment of the consequences of igneous activity at Yucca Mountain. The DOE and its contractors deserve credit for initiating and supporting this effort. The Panel's *Final Report* shows evidence of both independence and high technical quality. Much original work was conducted. Detailed reviews of the Panel's work by Board consultants can be found on the Board's Web site: www.nwtrb.gov.

The Panel agreed with much of the DOE's approach (e.g., the overall conceptual model of a rising dike intersecting waste emplacement drifts and localizing into a volcanic conduit that reaches the surface), but the Panel also recommended improvements. Because of the significance of the igneous issues, the Board recommends that the DOE give the most emphasis to three areas.

- The first area is the use of upgraded modeling techniques that take into account conditions such as compressible inviscid flow that may be present at repository depth. Past models based on incompressible flow may not give a true picture of dike behavior and magma-drift interaction. Such modeling also would help evaluate the likelihood of the so-called "dog leg" scenario as proposed by Woods and others in their 2002 article, *Modeling magma-drift interaction at the proposed high-level radioactive waste repository at Yucca Mountain, Nevada*. The Board concurs with the Panel that the likelihood of the generation of strong shock waves, as proposed by Woods and others, is negligible.

- The second area is the need to study aeromagnetic anomalies in the vicinity of Yucca Mountain that could signify buried volcanoes. Such studies may involve additional aeromagnetic surveys (at appropriate altitudes); drilling; and dating, which could help determine the existence, age, and volume of the possible volcanoes.

- The third area is the need to address subjects that were not within the range of the Panel's expertise, i.e., waste package-magma interaction and waste entrainment in both the volcanic eruption scenario and the groundwater release scenario. The Panel confined itself to evaluating magma-drift interaction in the volcanic eruption scenario. These subjects are of great importance in any consequence analysis. The DOE should address them using the advice of outside reviewers. The DOE also should consider experimental studies for analyzing and verifying key phenomena and parameters (e.g., chemical and mechanical effects of magma on waste packages).

In all of these investigations, it is very important that the DOE maintain an integrated team of field experts, modelers, engineers, and performance assessment analysts. If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of igneous activity, such modifications would need to be evaluated in terms of their overall impact upon repository operations and performance.

**Board Comments on Peña Blanca Natural Analogue**

At the meeting, two speakers touched on the Project's ongoing work at the possible analogue site at Peña Blanca in northern Mexico. Following the meeting, several Board and staff members visited Peña Blanca and observed the work first-hand. We are impressed with the progress being made.

The natural uranium deposits at Peña Blanca, particularly at the Nopal 1 site, form a unique natural analogue for many of the processes that would occur at the proposed Yucca Mountain repository. The uranium oxide deposit is in many ways similar to spent fuel. As at Yucca Mountain, it is located in oxidizing conditions in fractured, unsaturated welded tuff in a region of arid climate. There also are some important differences between Nopal 1 and Yucca Mountain, which Project scientists seem well aware of. The differences include the presence of some sulfates and iron in various forms at Nopal 1 and the relative lack of nonwelded-tuff layers. All in all, however, Peña Blanca offers the opportunity to test a number of the proposed models and assumptions underlying the DOE's analyses of Yucca Mountain and to examine alternatives to these models. They include, but are not limited to, models and assumptions related to waste form dissolution (the source term), unsaturated zone flow and transport, and the active fracture model.

The work at Peña Blanca can provide information for addressing important technical issues both in the short term and in the long term. The additional information that comes from studying this site could show that the repository system would perform better or not as well as current performance estimates now project. However, either way, these tests could increase understanding of the processes and their associated uncertainties. For this reason, the Board strongly recommends continued support for studies at this unique site.

Once again, the Board thanks you and the rest of the Yucca Mountain Project team for participating in the Board's May meeting. We look forward to continuing the Board's ongoing technical and scientific review and to commenting on Project activities in the future.

Sincerely,

Michael L. Corradini
Chairman

**Department of Energy**
Washington, DC 20585



October 10, 2003

Dr. Michael L. Corradini, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of June 30, 2003, providing the Nuclear Waste Technical Review Board's (Board) initial reactions to information presented by the U.S. Department of Energy (Department) at the Board's May 2003 Summer Board Meeting.

The Department appreciates the Board's continuing review of our activities as we continue development of science, design, and analysis, including a license application, for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department looks forward to the Board's detailed comments on the technical basis for our thermal analyses along with other aspects of the Department's licensing case.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
*Responses to Initial Comments from the Nuclear Waste Technical Review Board on U.S. Department of Energy presentations in the May 2003 Full Board Meeting*

**Responses to Initial Comments from the Nuclear Waste Technical Review Board (Board) on U.S. Department of Energy (DOE) presentations in the May 2003 Full Board Meeting**

**Safety Case:**
*The Board continues to believe that the concept of a "safety case", which is endorsed strongly by virtually all the major nuclear waste management programs abroad, has considerable merit. In fact, during the meeting, Project scientists were able to verbalize why they believe that a Yucca Mountain repository would isolate and contain waste effectively. An updated written narrative description similar to those oral comments would make the Project's approach to ensuring safety more transparent and understandable.*

**Response**:
The DOE agrees with the Board as to the importance of transparent communications. We are currently developing a series of technical basis reports to clearly document the Project's approach to ensuring safety of the repository system. These reports describe the various barriers of the repository system and the technical basis for performance of each barrier. In the May 2003 Board meeting, DOE presented an integrated basis for performance in the unsaturated zone above the drifts, in the in-drift environment, and in material performance. In the September 2003 meeting, we continued with this approach, addressing the detailed technical basis for flow and transport in the unsaturated zone and the saturated zone.

*The Project delivered three major presentations related to in-drift thermohydrology, in-drift thermohydrochemistry, and Alloy-22 corrosion. ...The Board's initial reaction is that potentially significant questions remain about the technical basis for the Project's thermal analyses. These questions include concerns about the initiation of localized corrosion and the technical basis underlying Project claims about capillary and vaporization barriers. The Board is in the process of carefully evaluating the DOE's presentations from the May Board meeting and will be preparing more detailed comments for the DOE on these subjects.*

**Response**:
The DOE looks forward to the Board's more detailed comments on the character of the unsaturated zone, the character of the in-drift environment, and materials performance.

As the DOE presented in the May and September Board Meetings, our technical basis continues to be based on: a) no significant corrosion above the boiling point of water because of a lack of seepage and the presence of primarily benign deliquescent brines; b) no significant corrosion at and near the boiling point of water because of the presence of primarily benign seepage and deliquescent brines and the presence of the drip shield; c) no significant corrosion below the boiling point of water because of the presence of primarily benign seepage brines and the presence of the drip shield.

The DOE has clearly indicated its intention to proceed to License Application with a design that would operate at a higher-temperature, but that retains the flexibility to be operated in a cooler mode should that be deemed necessary. Ongoing testing and analyses continue to improve the technical basis for the models used in the performance assessments over the range of possible postclosure thermal conditions. This testing and analytical program includes corrosion testing, prototype testing, near-field environment characterization using such tests as the Drift Scale Test, and unsaturated zone flow and seepage investigations. Finally, the DOE continues to develop the Total System Performance Assessment for the License Application where the above models are being integrated. This model will be used to conduct additional sensitivity analyses related to all barriers important to waste isolation, including the near-field environment and corrosion processes to better understand and communicate the technical basis for postclosure thermal conditions and impacts to total system performance. As additional testing and analyses are completed, the DOE will re-evaluate the technical bases and refine the operational parameters for the repository as needed. The DOE looks forward to continuing the discussion of the ongoing work and long-term strategy with the Board.

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

*The Board is pleased that the Project is committed to sponsoring long-term research on "outside the box" scientific and technical issues. It is not yet clear, however, how data and analyses from the Science and Technology Program will be integrated into the license application process or the performance confirmation effort mandated by the U.S. Nuclear Regulatory Commission.*

**Response**:

The Science and Technology Program is by design distinct from the mainline Office of Civilian Radioactive Waste Management (OCRWM) activity of developing the License Application. However, as the S&T Program completes various projects over the long-term, the results could impact either our

understanding of the way the repository will perform, or our repository design. In either case, the new information, including any data, models, analysis tools, new technologies, or different design approaches, will be used on a case-by-case basis either to amend the License Application or to support its technical basis. If anything adverse is discovered, it will be made available publicly as soon as feasible. However, the S&T Program does not have as an objective to support the initial License Application.

The relationship of the S&T Program to OCRWM's Performance Confirmation (PC) Program is to provide long-term technical support. Specifically, S&T will likely support some projects that could, if successful, provide better methods that the PC Program could use in carrying out its mandate. These might include developing improved measurement methods or improved instrumentation, or proving out novel proposed approaches for ascertaining whether a given aspect of repository performance is or is not performing according to expectations. If a new method or tool is successfully developed, OCRWM expects it to be integrated into an updated PC Program appropriately.

***Igneous Consequences Peer Review Report:***
*The Board recommends that the DOE give the most emphasis to three areas.*

*The first area is the use of upgraded modeling techniques that take into account conditions such as compressible inviscid flow that may be present at repository depth. Past models based on incompressible flow may not give a true picture of dike behavior and magma-drift interaction. Such modeling also would help evaluate the likelihood of the so-called "dog-leg" scenario as proposed by Woods and others. . . . The Board concurs with the Panel that the likelihood of the generation of strong shock waves, as proposed by Woods and others, is negligible.*

**Response:**
Current modeling of dike propagation uses a 2-dimensional hydrofracture code that includes free surface effects but is limited to an incompressible fluid model. Limited 2-dimensional modeling has also been done with a different code suggesting that the effects of order-of-magnitude changes in magma compressibility have a negligible effect on dike crack propagation. The DOE is considering development of a new hydrofracture code to include compressible fluids using the approach defined by the Igneous Consequence Peer Review Panel (Appendix 3.3 of the final report of the Peer Review).

The DOE intends to continue the 3-dimensional modeling completed thus far to investigate the effect of finite strike-length of the crack tip acceleration as the tip approaches the free surface. This latter activity addresses a potential non-

conservatism relevant to the "dog leg" scenario due to increased confinement as the crack tip reaches the free surface.

The current modeling presents magma flow as an incompressible viscous fluid and is expected to provide a reasonable basis for description of effusive flow from a dike into a drift. The DOE is considering 2- and 3-dimensional models that will permit better simulation of effusive flow and that will permit simulation of both pyroclastic flow and transitional flow between effusive and pyroclastic. These models will include multiphase flow with exchange of momentum and energy between phases. Inclusion of energy exchange will permit calculation of magma cooling rates in the dike, in a drift, and in a potential "dog-leg" crack growing out of a drift. Exchange of momentum is necessary for accurate portrayal of the multiphase flow.

The DOE is considering the feasibility of combining the 2- and 3-dimensional multiphase code for modeling simulation of transitional and/or pyroclastic flow in a dike to the new compressible hydrofracture code in order to develop a better understanding of the effect of such flow on dike propagation.

*The second area is the need to study aeromagnetic anomalies in the vicinity of Yucca Mountain that could signify buried volcanoes. Such studies may involve additional aeromagnetic surveys (at appropriate altitudes); drilling; and dating, which could help determine the existence, age, and volume of the possible volcanoes.*

**Response**:
The DOE has developed plans to initiate activities to evaluate potential buried volcanic centers in the vicinity of Yucca Mountain, including Crater Flat, Jackass Flat, and a section of the Amargosa Desert south of Crater Flat and Yucca Mountain. The investigations will consist of flying low altitude, combined aeromagnetic and electromagnetic surveys along a very closely spaced survey grid. These will be used to produce high-resolution aeromagnetic maps that will more accurately identify and define any potential buried volcanic centers including those anomalies identified from the 1999 U.S. Geological Survey (USGS) aeromagnetic data. A two-phased drilling program will initially drill up to six anomalies identified from the 1999 USGS aeromagnetic data. During the second phase, we will drill any new high-probability anomalies identified from the new aeromagnetic survey to confirm the presence or absence of buried volcanic centers. Chemical analyses and age dating will be performed on any basalts encountered from drilling. Additionally, limited age dating and chemical analyses will be performed on samples collected from the known volcanic centers in Crater Flat to better constrain eruptive sequences.

The field and laboratory program will begin in early fiscal year (FY) 2004 and continue through FY 2005. Information will be made available as the activities proceed, and a final report will be available in early to mid 2006. Information from this field and laboratory program will be used in an update of the Probabilistic Volcanic Hazard Assessment.

*The third area is the need to address subjects that were not within the range of the Panel's expertise, i.e., waste package-magma interaction and waste entrainment in both the volcanic eruption scenario and the groundwater release scenario. The Panel confined itself to evaluating magma-drift interaction in the volcanic eruption scenario. These subjects are of great importance in any consequence analysis. The DOE should address them using the advice of outside reviewers. The DOE also should consider experimental studies for analyzing and verifying key phenomena and parameters (e.g., chemical and mechanical effects of magma on waste packages).*

**Response**:
DOE recognizes the need to address subjects that were not within the range of the Panel's expertise. While DOE has no plans for conducting another peer review, we have developed a report, *Igneous Intrusion Impacts on Waste Packages and Waste Forms* (MDL-EBS-GS-000002). The purpose of this model is to assess the potential impacts of igneous intrusion on waste packages and waste forms, including deleterious dynamic, thermal and chemical impacts. The results (expected dynamic conditions) are corroborated by relevant experimental and industrial analogs. The models for waste package and waste form response during igneous intrusion consider the following: Zone 1, which includes the emplacement drift intruded by the basalt dike and Zone 2, which includes the emplacement drifts adjacent to Zone 1. This report combines the following assessments:

- Impacts of magma intrusion on the performance of engineered barrier system (drip shields, cladding and waste packages) in emplacement drifts in Zone 1, and the fate of waste forms,
- Impacts of intrusion-related thermal conduction/convection and emanating magma gases on the drip shields, cladding and waste packages in the Zone 2-emplacement drifts, adjacent to the intruded drift, and
- Impacts of intrusion on in-drift thermal and geochemical environments, including seepage hydrochemistry, which may affect the release, and fate and transport of radionuclides.

The results of this model study will provide inputs to the *Igneous Intrusion Groundwater Transport* and to the *Waste Form Degradation and Mobilization Sub-models* of the Total System Performance Assessment model.

Based on the numerical simulations of non-steady state heat conduction with radial flow and simulations of flow of volatile gas from cooling magma, the report concludes that thermal effects and effects of corrosive gases on waste packages in Zone 2-emplacement drifts will be negligible. The maximum expected temperature rise in the Zone 2-emplacement drifts is less than 10° C. The low-thermal conductivity and the 80-meter distance separating drifts limit the thermal effects. Constraints on the effects of corrosive gases include (1) the limited amount of initial gases that could exsolve from the cooling intruded magma and that could reach waste packages in Zone 2 emplacement drifts, and (2) the dominance of the gas phase by water.

Eventual release of radionuclides potentially trapped in the magma would be minimal because of several factors, including: (a) low dissolution rate of basalt by incoming seepage water, (b) the development of stable waste-mineral phases in the basalt, and (c) the fact that waste form solubility, and especially fissile uranium solubility, is controlled by solution pH. Solution pH for seepage water equilibrated with basalt is in a range that causes precipitation of solubilized radionuclides and sorption of waste mineral phases in the basalt. Based on the results of the preceeding analyses, DOE will consider experimental studies (e.g., chemical and mechanical studies) to the extent that they are required to support our license application case.

*In all of these investigations, it is very important that DOE maintain an integrated team of field experts, modelers, engineers, and performance assessment analysts. If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of igneous activity, such modifications would need to be evaluated in terms of their overall impact upon repository operations and performance.*

**Response**:
The DOE agrees that it is essential to maintain an integrated team to complete these investigations as well as any future analyses involving volcanism and engineered barrier performance. The DOE is currently evaluating the potential effects (beneficial and adverse) of using durable barriers to limit flow of magma from potential future dikes that could intersect the repository as an integrated effort that includes experts in disruptive events and waste package analyses. This and any other proposed changes to repository design to mitigate the potential effects of igneous activity will be processed through our design control procedures to evaluate the overall impact on repository operations and performance.

-7-

***Peña Blanca***

*. . . Peña Blanca offers the opportunity to test a number of the proposed models and assumptions underlying the DOE's analyses of Yucca Mountain and to examine alternatives to these models. They include, but are not limited to, models and assumptions related to waste form dissolution (the source term), unsaturated zone flow and transport, and the active fracture model. . . . The additional information that comes from studying this site could show that the repository system would perform better or not as well as current performance estimates now project. However, either way, these tests could increase understanding of the processes and their associated uncertainties. For this reason, the Board strongly recommends continued support for studies at this unique site.*

**Response:**
The DOE agrees that the ongoing work at Peña Blanca provides an opportunity to examine alternative models and to test proposed models and assumptions. A scientific plan, supported by the S&T Program, is under development for expanded studies at this site in the areas of hydrology, transport, and geochemistry. This plan will be considered for funding in FY 2004.

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

October 21, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

In its June 30, 2003, letter to you, the Nuclear Waste Technical Review Board promised a more detailed evaluation of data and analyses presented at the Board's May 2003 meeting. This letter briefly summarizes our concerns about waste-package corrosion during the thermal pulse — particularly localized corrosion but also general corrosion. In addition, we are nearing completion of a report on the technical bases for these and related concerns about various thermal pulse issues. We will provide the report to you soon.

1. *Localized Corrosion.* Localized corrosion processes are particularly insidious because initiation is difficult to predict and propagation rates can be very rapid. Information on localized corrosion (e.g., pitting, crevice corrosion, stress corrosion cracking) rates in representative repository environments is critical to predicting waste-package effectiveness. As illustrated by the attached overheads provided to the Board at recent meetings, data emerging both from the Yucca Mountain Project and from the Center for Nuclear Waste Regulatory Analyses (Center) suggest to the Board that crevice corrosion of Alloy 22 is likely to initiate during the thermal pulse (approximately the first thousand years after repository closure, when temperatures will exceed 95ºC for the current repository design). Project data show that initiation of crevice corrosion during the thermal pulse is likely in concentrated brines (with or without nitrates) at temperatures well below the peak waste-package surface temperatures expected in the Department's proposed repository design. Crevice corrosion initiated during the thermal pulse is likely to propagate during the remainder of the thermal pulse and also is likely to continue even after the thermal pulse, at temperatures below 95°C.

   Work at the Center and elsewhere indicates to the Board that welds and thermal treatment (aging) increase susceptibility to crevice corrosion. As currently designed, the waste package has both welded areas (i.e., closure welds) and many opportunities for crevice formation. Redesign studies for reducing or eliminating areas of increased susceptibility to localized corrosion may be a worthwhile option.

2. *General Corrosion.* In choosing candidate materials of construction, an important line of inquiry is the general (uniform) corrosion rate. If the general corrosion rate is known with confidence, then one can determine the mass of material (or thickness) required to perform for the life of the system. In the case of the Project, one needs corrosion-rate information in representative repository environments. Most corrosion data reported to date are for 95ºC (the approximate boiling point of pure water at the altitude of the repository site) or lower. These data may constitute an adequate technical basis if the surface temperatures of the waste packages in the repository never exceed 95ºC. Few data exist, however, at the higher temperatures of the thermal pulse. Moreover, the nature of the environments in contact with the waste packages (or drip shields) is not well known under such conditions. Concentration processes of various kinds may lead to aggressive chemistries.

The concern about localized corrosion during the thermal pulse is one of the data in hand showing that localized corrosion is likely. In contrast, the concern about general corrosion during the thermal pulse is one of corrosion-rate uncertainty due to the lack of corrosion data. That the aqueous environments necessary for corrosion exist during the thermal pulse is primarily due to deliquescence of salts. In the higher part of the thermal pulse range, deliquescence can be attributed mainly to chloride salts with divalent cations.

The Project data and the Center data are consistent in that both sets of data cast doubt on the extent to which the waste package will be an effective barrier under the repository conditions that have been presented to the Board. The waste package is both a key barrier and an extremely important element in providing defense-in-depth. Given the importance of the waste package to the repository, the Board requests that the Department address the Board's concerns about corrosion, particularly localized corrosion, during the thermal pulse.

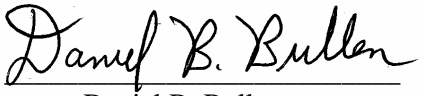
The Board believes that total system performance assessment should not be used to dismiss these corrosion concerns.

As you are aware, the Board's responsibilities include evaluating the technical and scientific validity of the Department's activities related to the repository and reporting the Board's findings, conclusions, and recommendations. Our role is that of an independent technical advisor. We know that the Department's decision-making process must take into account not only technical and scientific factors but also many others. Nevertheless, because of the seriousness of these corrosion concerns, we strongly urge you to reexamine the current repository design and proposed operation. The Board believes that the high temperatures of the current design and operation will result in perforation of the waste packages, with possible release of radionuclides. The data currently available to the Board, provided by the Project and the Center, indicate that perforation is unlikely if waste-package surface temperatures are kept below 95ºC.

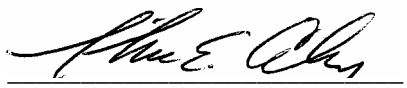
Sincerely,

Michael L. Corradini, Chairman

Mark D. Abkowitz

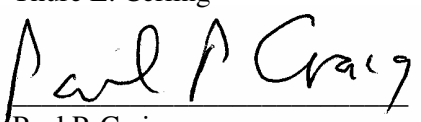


Daniel B. Bullen

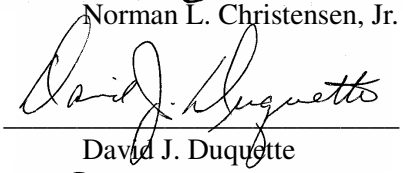


Thure E. Cerling

Norman L. Christensen, Jr.

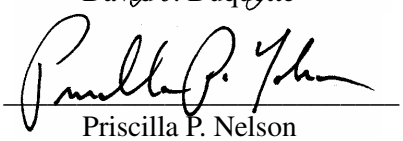


Paul P. Craig



David J. Duquette

Ronald M. Latanision



Priscilla P. Nelson

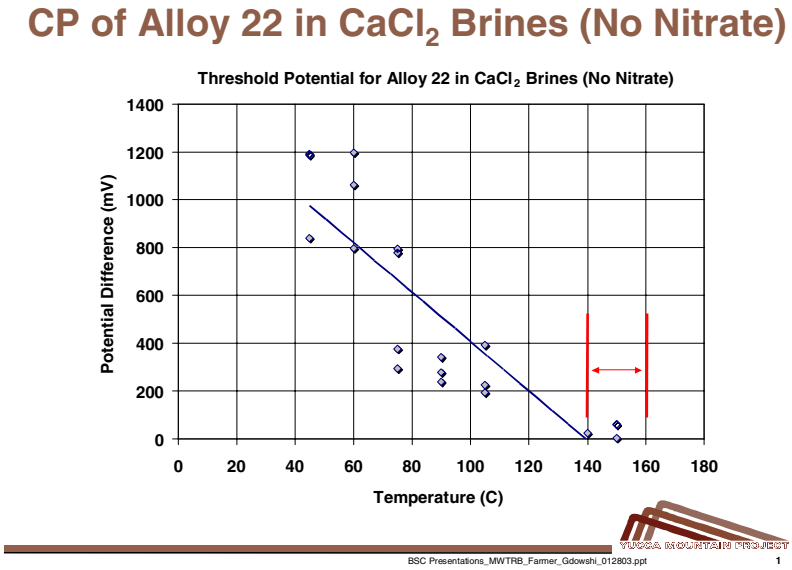
Richard R. Parizek

Attachment: Seven overheads presented at the Board's January and May 2003 meetings.

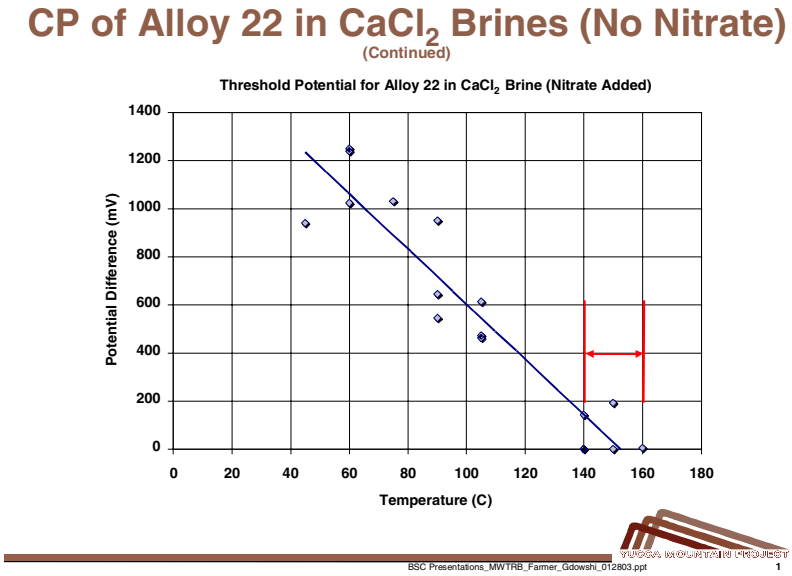
ATTACHMENT TO OCTOBER 21, 2003, LETTER FROM THE BOARD TO DR. CHU

This attachment contains seven overheads presented at the Board's January and May 2003 meetings. The first three overheads were part of presentations by Dr. Joseph C. Farmer of the Department of Energy's Lawrence Livermore National Laboratory. The next four overheads were part of a presentation by Dr. Gustavo A. Cragnolino of the Nuclear Regulatory Commission's Center for Nuclear Waste Regulatory Analyses.

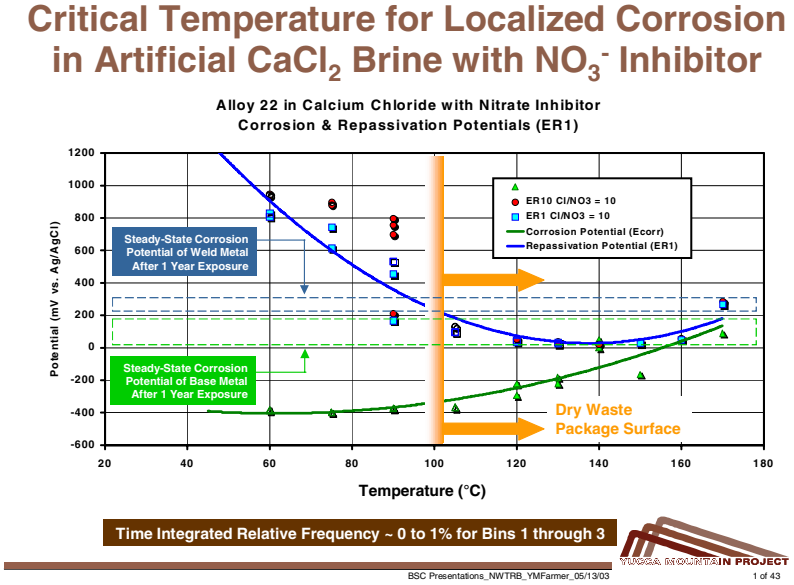
This figure is an overhead from Dr. Farmer's presentation at the January 28, 2003, Board meeting in Las Vegas. Localized corrosion is virtually certain to initiate when the Potential Difference falls below 0. For Alloy 22 in a concentrated solution of calcium chloride with no nitrate added, the overhead indicates that the Potential Difference is below 0 for temperatures of approximately 140ºC and higher. (Peak waste package surface temperatures in the current design are approximately 180ºC.)



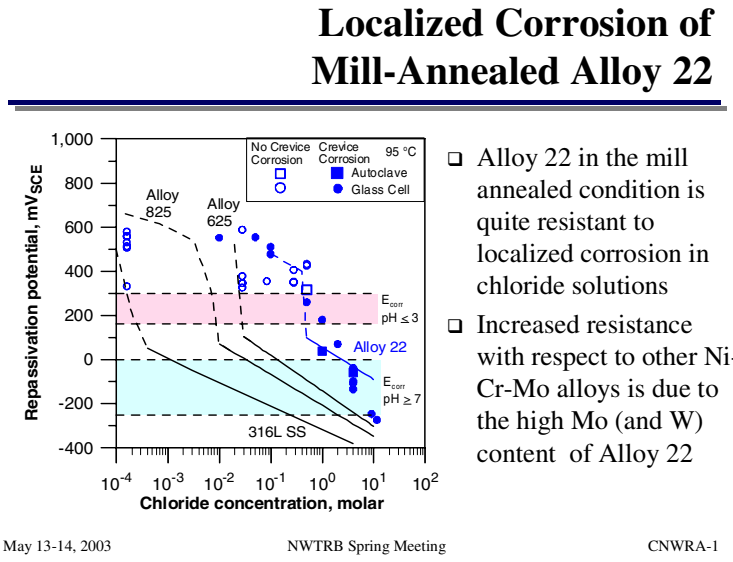

This figure is another overhead from Dr. Farmer's presentation at the January 28, 2003, Board meeting. (There is an error in the title. Instead of "No Nitrate," it should read "Nitrate Added.") Again, localized corrosion is virtually certain to initiate when the Potential Difference falls below 0. For Alloy 22 in a concentrated solution of calcium chloride with nitrate added, the overhead indicates that the Potential Difference is below 0 for temperatures of approximately 150ºC and higher.



This figure is an overhead from Dr. Farmer's presentation at the May 13, 2003, Board meeting in Washington, D.C. Note the dashed boxes. They indicate that base-metal steady-state corrosion potential moves in a noble (positive) direction with time and that welded-metal corrosion potential moves even farther in that direction with time, indicating increasing susceptibility to crevice corrosion with aging time and in welded structures. Although the overhead appears to state that waste package surfaces are dry above approximately 120ºC, deliquescence of salts in the dust on waste package surfaces can cause brines to form at temperatures up to approximately 150º-160ºC.

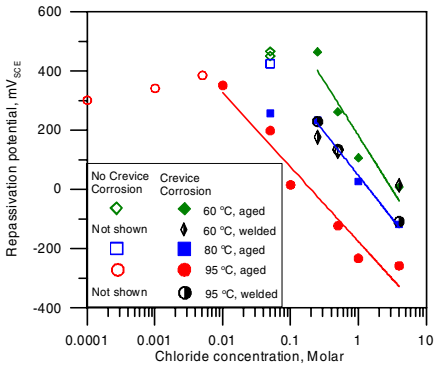



This figure to the right is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting in Washington, D.C. Note that Alloy 22 is more resistant to localized corrosion than other nickel-chromium-molybdenum alloys (alloys 625 and 825) and than a nickel-chromium alloy (316 stainless steel).



This figure is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting. It illustrates the increased susceptibility of welded and thermally aged Alloy 22 in comparison to mill-annealed material.

## Effect of Fabrication Processes on Localized Corrosion

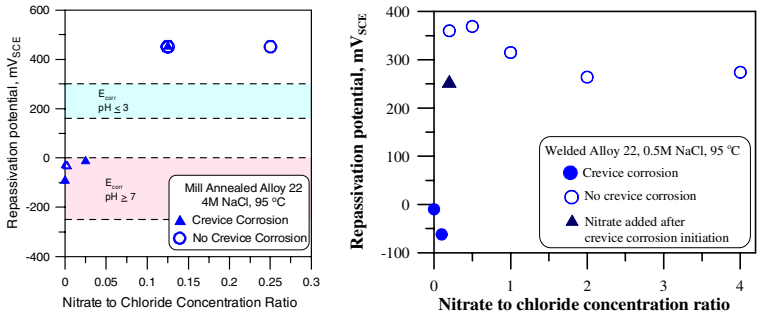



- Welding and short-term thermal aging increase localized corrosion susceptibility
- Localized corrosion observed at lower [$Cl^-$] and lower temperatures compared to the mill annealed condition

May 13-14, 2003 NWTRB Spring Meeting CNWRA-1

This figure is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting. It illustrates the beneficial effect of nitrate on localized corrosion susceptibility of Alloy 22 at 95ºC. There is an error in the next-to-last line. Rather than "1.2 for mill-annealed material," it should read "0.12 for mill-annealed material."

## Effect of Nitrate on Localized Corrosion of Alloy 22

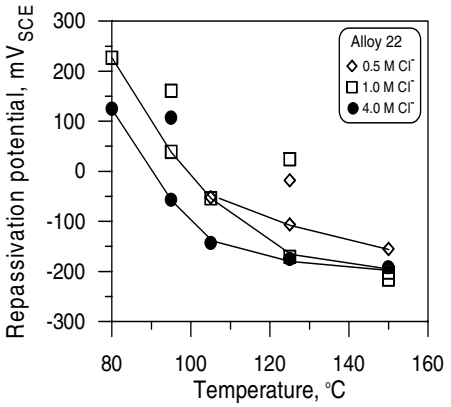



- Nitrate is an efficient inhibitor of localized corrosion induced by chloride
- Critical nitrate to chloride molar concentration ratio is 1.2 for mill-annealed material and 0.2 for welded material

May 13-14, 2003 NWTRB Spring Meeting CNWRA-1

This figure is an overhead from Dr. Cragnolino's presentation at the May 14, 2003, Board meeting. It illustrates how repassivation potential decreases with temperature.

## Effect of Temperature on Localized Corrosion




- $E_{rcrev}$ measured using creviced specimens in autoclave systems
- Significant decrease of $E_{rcrev}$ with increasing temperature from 80 to 105 °C
- At higher temperatures $E_{rcrev}$ values tend to level off

May 13-14, 2003 NWTRB Spring Meeting CNWRA-1

**Department of Energy**
Washington, DC 20585

QA: N/A

October 27, 2003

Dr. Michael L. Corradini
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini and Board Members:

I have received your letter of October 21, 2003, transmitting the Board's comments on the data and analyses we presented at the Board's May 13-14, 2003, meeting. I look forward to the report containing the detailed basis for the Board's comments, and will provide a response after there has been time to review it.

I am deeply disappointed by the premature release of the letter's contents. As a result, I am providing an immediate response so that I may register my concern about statements in the letter that, taken out of context, might be misunderstood or misrepresented. I am referring specifically to the definitive statements that crevice corrosion is "likely to initiate" during the thermal pulse, that "the data in hand [show] that localized corrosion is likely," and that "the high temperatures of the current design and operation will result in perforation of waste packages… ." I do not agree that the data cited by the Board support such definitive conclusions.

As we presented in the May meeting, the corrosion testing results cited in the Board's letter provide an incomplete representation of what we expect to occur in the likely environment inside the repository drifts. The Board's conclusions did not acknowledge the dependence of those results on the existence of extreme and unlikely environmental conditions, nor did the letter say whether the Board believes that such conditions are likely to occur. The outcome is an incorrect implication that the data show that localized corrosion and waste package perforation are "likely to" or even "will" occur.

With reference to the statement "that total system performance assessment should not be used to dismiss these corrosion concerns," I want to assure you that we will not dismiss the Board's corrosion concerns. However, as you know, the performance assessment is a required part of the demonstration of compliance with safety requirements established by the Environmental Protection Agency and the Nuclear Regulatory Commission.

Finally, I appreciate the fact that the Board's approach relates to the thermal operating conditions of the repository, and not to the ability to dispose of waste safely at Yucca Mountain.

Once again, we look forward to the Board's forthcoming report that we anticipate will provide a more complete basis and context for the Board's conclusions.

Sincerely,

Dr. Margaret S. Y. Chu, Director
Office of Civilian Radioactive
Waste Management

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

November 25, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

We are pleased to transmit a technical report prepared by the Nuclear Waste Technical Review Board (Board) that includes additional analyses supporting the Board's conclusions related to corrosion in its October 21, 2003, letter to you. Although the enclosed report touches on a variety of corrosion issues, its main focus is the potential for deliquescence-induced localized (or crevice) corrosion of the Alloy 22 waste packages in the Department of Energy's proposed high-temperature repository design. The conditions used by the Board for its analyses were presented by the DOE at the Board's January and May 2003 meetings. The report also evaluates the vaporization barrier and capillary barrier concepts that were discussed at the May meeting. Appended to the report are some additional technical comments by Dr. Michael Corradini.

Based on its review of data gathered by the DOE and the Center for Nuclear Waste Regulatory Analyses, the Board believes that all the conditions necessary to initiate localized corrosion of the waste packages will likely be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus it is likely that deliquescence-induced localized corrosion will be initiated during the thermal pulse. Corrosion experiments indicate that localized corrosion is likely to be initiated if waste package surface temperatures are above 140°C and if concentrated brines, such as would be formed by the deliquescence of calcium and magnesium chloride, are present. Limited data examined to date indicate that dust, which would be present in the proposed tunnels and which would be deposited on waste packages, contains calcium chloride and magnesium chloride salts in amounts sufficient for the development of concentrated brines through deliquescence. (Crevices are widespread on the waste packages, arising from their design as well as from contacts between the metal and dust particles.)

Thus, the Board believes that under conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse. Once started, such corrosion is likely to propagate rapidly even after conditions necessary for initiation are no longer present. The result would be perforation caused by localized corrosion of the waste packages, with possible release of radionuclides.

The Board is aware that the DOE believes that the conditions in the repository will not promote significant corrosion. The DOE points to data, gathered using thermogravimetric apparatus (TGA), to demonstrate that the conditions necessary to initiate localized corrosion will be present only briefly. The Board has evaluated these data and finds them inadequate to support the DOE's claim for the following reasons.

- Brines used in the TGA experiments may not be representative of those that would form on the waste packages because of deliquescence.
- The metallic coupons used in the experiments did not contain crevices.

- The TGA experiments have been run only over narrow ranges of temperature and relative humidity.
- The experimental apparatus is an "open" system that may not approximate short-term behavior of the microenvironment associated with crevices.
- The results from other experiments conducted by the DOE seem contradictory.

The DOE also holds that the conditions under which localized corrosion might occur are extreme and unlikely. The information provided to the Board to date, however, does not form a compelling basis for that contention. For example, the DOE maintains that the presence of nitrates and an insufficient amount of calcium chloride in the proposed repository tunnels will limit localized corrosion. The DOE's own data, however, indicate that nitrate may not be protective at temperatures higher than 140°C. Furthermore, as noted above, the Board has concluded that more than enough chloride would be present in the dust from the tunnels to lead to widespread localized corrosion.

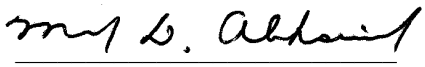
Thus, the DOE's belief that the geochemical environment on the waste package surfaces *will not* lead to corrosion lacks a strong technical basis. Absent that basis, the Board cannot ignore the clear and unambiguous implications of the corrosion and deliquescence experiments.

As stated in our October 21 letter, the Board realizes that decision-makers must take into account considerations beyond technical and scientific ones when making program decisions. However, because of the significance of the waste packages to the proposed repository system, the Board believes that the potential for localized corrosion during the thermal pulse should be addressed. From a technical perspective, the problems related to localized corrosion that are described by the Board in the enclosed report could be avoided if the repository design and operation were modified. The data currently available indicate that perforation of the waste packages caused by localized corrosion is unlikely if their temperatures are kept below 95ºC.

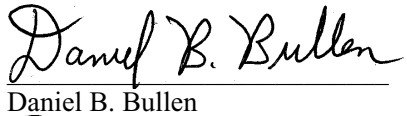
The Board looks forward to continuing its review of the DOE's investigations at Yucca Mountain, including those dealing with the integrity of the waste packages.

Sincerely,

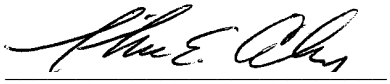
Michael L. Corradini, Chairman



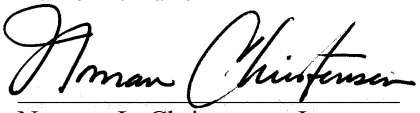
Mark D. Abkowitz



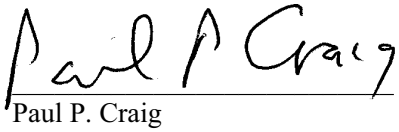
Daniel B. Bullen



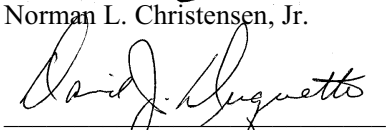
Thure E. Cerling



Norman L. Christensen, Jr.

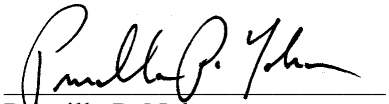


Paul P. Craig

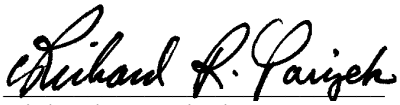


David J. Duquette

Ronald M. Latanision



Priscilla P. Nelson



Richard R. Parizek

QA: N/A

**Department of Energy**
Washington, DC 20585

December 17, 2003

Dr. Michael Corradini
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Corradini:

Thank you for your letter of November 25, 2003, transmitting the Board's technical report, *An Evaluation of Key Elements in the U.S. Department of Energy's Proposed System for Isolating and Containing Radioactive Waste*. This report provides additional analyses to support the Board's October 21, 2003, letter, which summarized the Board's concerns relating to waste package corrosion during the thermal pulse. In addition, I have received your letter of December 4, 2003, announcing the Board's decision to conduct meetings of the Engineered System and the Waste Management System Panels, instead of a Full Board meeting, in January 2004.

With respect to the Board's technical report, we are in the process of reviewing this report, but I would like to provide some preliminary comments. While the Board has identified some valid issues with the technical basis for aspects of the U. S. Department of Energy's (DOE's) analysis of corrosion processes during the thermal pulse, I am concerned about certain conclusions in this report. As first noted in my October 27, 2003, letter, I am especially concerned about the Board's conclusions that under the conditions associated with our current design, "widespread corrosion is likely to be initiated during the thermal pulse" and this corrosion is "likely to propagate rapidly even after conditions necessary for initiation are no longer present." Our analyses do not suggest such results and I do not believe that the data presented in the Board's report support such strongly stated conclusions. The report also fails to acknowledge briefings on the DOE's ongoing testing and analysis program that is structured to address some of the issues raised by the Board.

I anticipate that our review of your report will be completed in February 2004. After we have completed this review, we would appreciate the opportunity to discuss the report during a Full Board meeting – perhaps in the March timeframe. The purpose of this discussion would be to develop a common understanding of the technical issues related to seepage, the in-drift environment, and localized corrosion. Instead of formal DOE

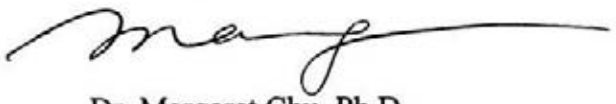
presentations, I propose a round table presentation and discussion of the issues as an appropriate forum to develop a common understanding of the Board's concerns and DOE's perspective on these issues. The Board used this approach in their meeting on multiple lines of evidence in April of 2001 and the results were well received.

The Board's letter of December 4, 2003, provides suggested topics for DOE presentations at the Board's panel meetings scheduled for January 20 and 21, 2004. With respect to the panel meeting on the waste management system, the DOE will provide the requested presentations on the status of DOE transportation planning and the interface between the transportation system and the Yucca Mountain surface facilities.

For the panel meeting on the engineered system, I believe it is premature, as noted above, for the DOE to address the Board's November report at that time. Given the critical nature of the Board's concerns, I believe this discussion should be addressed in a Full Board Meeting after the DOE has completed a technical review of the Board's report. Our respective staffs are discussing alternative presentations for that meeting.

Claudia M. Newbury of my staff will be working with Daniel Fehringer and Carl DiBella of the Board staff on the details and planning for these two panel meetings. I appreciate the time the Board has taken to develop and communicate its views, and I look forward to continuing our dialogue on important issues.

Sincerely,



Dr. Margaret Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

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

December 4, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board has decided to conduct two panel meetings on January 20 and 21, 2004, in Las Vegas, rather than the full Board meeting that was scheduled for the same week and location. Specifically, the Board's Panel on the Engineered System will conduct a meeting on Tuesday, January 20, and the Board's Panel on the Waste Management System will conduct a meeting on Wednesday, January 21. Both meetings will be held at the Crowne Plaza Hotel. Principal topics that will be considered at the Engineered System Panel meeting will be waste-package corrosion, environment on waste package surfaces, and design. The focus of the Waste Management System Panel will be issues related to the transportation of spent nuclear fuel and high-level waste.

Since OCRWM's appropriation for FY2004 is now settled, we very much would appreciate an update from you on OCRWM's current activities and plans for the remainder of the fiscal year. Because it appears that all Board members will be at the January 20 meeting, we would prefer to have your update then if that is convenient for you.

**Panel on the Engineered System**

In an October 21, 2003, letter to you, the Board expressed its serious concerns about the potential of waste-package corrosion during the thermal pulse. On November 25, 2003, the Board sent you a report discussing the technical basis for the Board's concerns and other topics. We would like the DOE to take as much time as you think necessary at the January 20 meeting to address the issues in these two documents. The specific subject areas to be addressed would be up to you. They could include, for example, corrosion data obtained since Spring 2003 and plans for obtaining additional corrosion data, amplification of the deliquescence discussion at last May's Board meeting, plans for analyses of airborne dusts or ECRB dusts, responses to the Board's concerns about temperature and relative humidity calculations, etc. Time permitting, we would also appreciate updates on the waste package prototype program, surface and subsurface facility design (particularly recent changes and ground support design), waste package/drip

shield/emplacement pallet/invert/engineered barrier system design, and other design topics the DOE is prepared to discuss. Dr. Ron Latanision, who chairs the Panel on the Engineered System, will chair this panel meeting. Dr. Carl Di Bella is the staff member coordinating this meeting for the Board.

**Panel on the Waste Management System**

The transportation meeting will focus on strategic planning considerations related to the potential shipment of commercial spent fuel and high-level waste to Yucca Mountain. The purpose of the meeting is to hear directly from key stakeholders who could have operational or oversight responsibilities for the safety and/or security of such shipments at some point during loading, in-transit, and/or unloading activities. Speakers will be asked to address the following questions:

1. What are your key Yucca Mountain transportation safety and security concerns?
2. How have you been able to address these concerns based on the information and resources that the DOE has provided to date?
3. What concerns have you been unable to address? What does the DOE need to provide to allow this to happen?
4. How long will it take you to address these outstanding concerns once the DOE has provided what you need?

We plan to invite speakers who are knowledgeable about all aspects of a Yucca Mountain transportation system, including representatives of utilities, truck and rail operators, cask manufacturers, state and local governments, and veterans of previous shipping campaigns. We request two presentations by the DOE: one on the interface between the transportation system and Yucca Mountain surface facilities, and another overview presentation of the status of DOE transportation planning. Dr. Mark Abkowitz, member of the Panel on the Waste Management System, will chair this panel meeting. Dr. Dan Fehringer is the staff member coordinating this meeting for the Board.

We are looking forward to two days of very interesting and productive meetings.

Sincerely,

Michael L. Corradini
Chairman

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

December 16, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board thanks you and the rest of the Yucca Mountain Project team for participating in our September meeting in Amargosa Valley. Your program overview and the presentations by your staff and contractors were very clear and helpful to the Board.

We were pleased to hear that you have completed your selections for key management positions within the Office of Civilian Radioactive Waste Management. It appears that you have assembled a highly qualified and competent management team.

Our observations and recommendations from this meeting are presented below.

**Issues Relating to Natural Characteristics of Yucca Mountain**

*Igneous scenarios.* According to the DOE's estimates, igneous scenarios may dominate the risk to humans from a Yucca Mountain repository. To date, it appears that the DOE intends to pursue only one of the three recommendations made by the Board in its June 30, 2003, letter—study of aeromagnetic anomalies near the Yucca Mountain site. The Board repeats its recommendation that the DOE also conduct modeling studies of compressible fluids and studies of waste package-magma interaction and waste entrainment.

*Enhanced borehole studies.* As plans are developed for drilling aeromagnetic anomalies near Yucca Mountain, the Board encourages the DOE to consider additional development of those boreholes as monitoring wells to obtain hydraulic head, water chemistry, and related hydrogeologic data at relatively small additional cost. Additional hydrogeologic data from these areas may resolve differing hypotheses regarding the direction of water flow in the saturated zone and may provide additional information about the ability of the saturated zone to function as a barrier to migration of radioactive materials.

*Chlorine-36.* The Board encourages the DOE to resolve discrepancies in chlorine-36 studies and agrees with the decision to commission a third-party review that includes integrated chlorine-36 and other bomb-pulse data to help address inconsistencies. Such an integrated

methodology should include the measurement of tritium. If an accepted integrated methodology could be developed, it could enhance understanding of hydrogeologic controls on fast-path flows into the repository and yield a conceptual model consistent with both chlorine-36 and other bomb-pulse data. The Board believes that resolving chlorine-36 discrepancies will require a "root cause" analysis that lays out each step in the procedure, how the discrepancies were addressed by each of the two analytical groups, and what each set of measurements has in common as well as what differences exist and the potential reasons for these differences and actions for resolving them.

**Issues Relating to Potential Waste Package Corrosion**

*Microbial activity.* Decreasing nitrate concentrations with depth, as shown in one of Bo Bodvarsson's slides, suggest microbial activity. A waste package design that relies on nitrate to reduce the likelihood of localized corrosion must take into account the effects of microbial activity on nitrate concentrations both before and during the thermal pulse.

*Gas pressure.* The maximum temperature at which brines can exist on waste package surfaces is a strong function of gas pressure. Elevated pressures allow brines to exist at higher temperatures, increasing the likelihood that corrosion will be initiated. Even transient elevated pressures could be important. The DOE should provide a careful and complete explanation of gas pressures during the thermal pulse within the drift environment.

**Issues Relating to Management and Communication**

*Quality/schedule tradeoffs.* The Board appreciates John Arthur's assurance that the license application schedule is not constraining the quality of work within the Yucca Mountain project. The Board strongly agrees with the DOE that a license application should be filed only when appropriate quality standards have been met. A schedule-driven approach to quality management can potentially compromise the safety culture surrounding the preparation of the license application, thereby making the project vulnerable to poor decision-making. The Board emphasizes the importance and inherent long-term efficiency in "taking the time to do it right."

*Repository performance confirmation.* With an operational period that may extend beyond repository closure, it appears that performance confirmation may be a component of the DOE's proposed radioactive waste disposal system that will span licensing, construction, and possibly operation. Thus, performance confirmation holds the possibility of enhancing confidence in repository prediction not only by "confirming" DOE models but also by testing the underlying conceptual, physical, and mathematical bases of those models. The Board encourages the DOE to have a clear understanding of what it means by performance confirmation and integrate it thoroughly with performance assessment and repository design. This includes the need to establish formal management practices that ensure that appropriate interactions occur between these system components. Moreover, the Board believes that the performance confirmation program can benefit significantly from the input of the interested public and affected parties.

*Program integration and communication.* The Board believes that the technical basis documents being developed for the Yucca Mountain Project have significant potential for improving program integration and enhancing program communication with the wider technical community as well as the general public. For gaining the maximum benefit from these documents, integrating their most important conclusions into a concise description of the safety case for a Yucca Mountain repository will be important. However, if the documents are not well integrated or if they contain technical errors, then communication of the safety case to the broad scientific and public audiences will be weakened. Where appropriate, the discussion of relevant analogs can be used as a line of evidence and enhance the DOE's communication.

The Board reiterates the need for early and continuous involvement of interested members of the public and affected parties in transportation planning. This involvement is critical to develop a safe and secure transportation system and to engender public confidence in system performance.

Once again, the Board thanks you and the rest of the Yucca Mountain Project team for participating in the Board's September meeting. We look forward to continuing the Board's ongoing technical and scientific review and to commenting on Project activities in the future.

Sincerely,

Michael L. Corradini
Chairman