UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 6, 1998

Dr. Stephan J. Brocoum
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SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION COMMENTS ON THE U.S. DEPARTMENT OF ENERGY TOTAL SYSTEM PERFORMANCE ASSESSMENT

Dear Dr. Brocoum:

In March 1998, U.S. Nuclear Regulatory Commission (NRC) and U.S. Department of Energy (DOE) staff met to discuss their respective performance assessments of the proposed repository at Yucca Mountain, Nevada. This was the most recent of three NRC-DOE technical exchanges on performance assessment activities since July 1997. DOE's approach to its total system performance assessment supporting the viability assessment (TSPA-VA) has continued to evolve since July 1997. Moreover, we are aware, from the briefing presented to the Nuclear Waste Technical Review Board (NWTRB) in April 1998, that some aspects of DOE's performance assessment have changed since the March Technical Exchange. Indications of these changes were present at the NWTRB briefings, which also included information on DOE's approach to disruptive events that was not part of the March technical exchange. The focus of this correspondence is the TSPA-VA as presented at the most recent performance assessment technical exchange, but it also addresses disruptive events as described in the April NWTRB meeting.

The staff believes that each of the three technical exchanges was very productive and appreciates the opportunity afforded by the exchanges to hear the perspectives of DOE and other participants on the results of NRC staff performance assessments. The exchanges provided NRC an opportunity to see the evolution of TSPA-VA and to understand the bases DOE is using to support its modeling approach, substantially facilitating our review of the viability assessment. The exchanges also provided NRC staff with an integrated look at TSPA-VA that is unavailable through other means. The open and comprehensive discussions enabled NRC to offer DOE immediate feedback on DOE's modeling approaches. The enclosed comments are intended to complement the earlier feedback by providing DOE with a written account of the larger issues identified with TSPA-VA.

NRC is aware of the schedule that DOE has established to complete the TSPA-VA by September 30, 1998. We understand DOE will need to rely on models as developed through June 1998 to meet this schedule. It is not the staff's intent to disrupt this schedule. It is, however, hoped that DOE will incorporate these comments in its assessment of future work that should be undertaken to support a defensible license application. The enclosed NRC comments are forwarded to facilitate DOE's efforts to identify — and document in the viability assessment — the future work that may be needed to develop a complete license application.

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Letter to S. Brocoum from M. Bell dated: July 6, 1998

cc: S. Rousso, OCRWM
R. Loux, State of Nevada
B. Price, Nevada Legislative Committee
J. Meder, Nevada Legislative Counsel Bureau
R. Dyer, YMPO
C. Einberg, DOE/Wash, DC
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One positive outcome from the series of technical exchanges has been DOE's demonstrated flexibility in modifying its approach in response to exchanges of information and technical discussions at previous meetings. However, the NRC staff has continuing concerns with some aspects of DOE's performance assessment as they relate to an acceptable license application. The concerns are documented in the enclosed comments, most of which have been raised at the previously mentioned technical exchanges. These concerns are grouped as: total system performance assessment modeling and documentation, engineered system performance, natural system performance, and procedural issues.

As progress towards submittal of a license application continues, NRC staff will monitor developments in DOE activities related to performance assessment and will seek to resolve specific performance assessment-related issues through acceptance criteria described in the total system performance assessment methodology issue resolution status report. In this context, the staff will use the formal performance assessment document supporting the viability assessment to identify areas where there is general agreement or potentially significant disagreement in the assessment of repository performance. We believe that in this way progress towards issue resolution in the area of total system performance assessment can continue.

Sincerely,

Michael J. Bell, Acting Chief
Performance Assessment and High-Level
Waste Integration Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated

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As progress towards submittal of a license application continues, NRC staff will monitor developments in DOE activities related to performance assessment and will seek to resolve specific performance assessment-related issues through acceptance criteria described in the total system performance assessment methodology issue resolution status report. In this context, the staff will use the formal viability assessment to identify areas where there is general agreement or potentially significant disagreement in the assessment of repository performance. We believe that in this way progress towards issue resolution in the area of total system performance assessment can continue.

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NAME	JFirth/jcg JRF		KMcConnell KMM		KStablein		NEisenberg		MBell	
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U.S. Nuclear Regulatory Commission (NRC) Staff Comments on the U.S. Department of Energy (DOE) Performance Assessment for Yucca Mountain

Total System Performance Assessment Modeling and Documentation

1. Radionuclides Tracked in the Performance Assessment

The current DOE analysis uses a limited number of radionuclides for calculating doses. It is not clear that DOE has adequately articulated its basis for limiting the number of radionuclides in the total system performance assessment supporting the viability assessment (TSPA-VA). DOE should document how the initial inventory was screened and address how the results may have been impacted by using the limited set of radionuclides.

The results of performance assessments (calculated doses) can be underestimated by excluding radionuclides. The set of important radionuclides may be influenced by design specifications, modeling assumptions, scenarios analyzed, and the results of site characterization; therefore, screening must be consistent with these considerations and may need to be reevaluated if significant changes occur. Presumably DOE screened radionuclides from a larger list on the basis that either the radionuclide did not substantially contribute to the dose or the impact of the radionuclide was addressed through the dose conversion factors that assumed equilibrium conditions with parent radionuclides. Although screening of radionuclides from the TSPA-VA may be appropriate, both the approach used to screen radionuclides and the potential impact of not considering the full set of radionuclides in TSPA-VA need to be documented.

2. Consideration of All Significant Features and Processes in the Performance Assessment

DOE's approach to treating, or omitting, features and processes in TSPA-VA is unclear. The potential impact of omitted features and processes on the results of performance assessment should also be addressed.

DOE's modeling of the near-field environment is an example of the need to document the rationale for excluding features or processes. There is an apparent inconsistency in how the cementitious liner material is included in the analysis. The cementitious liner material is considered in the near-field chemistry calculation, but is not considered in the hydrologic models, although it will affect seepage while intact and may affect flow within the drift after it has collapsed. In the absence of a detailed understanding of coupled thermal-mechanical-hydrologic-chemical effects, DOE should approximate coupled behavior so that unfavorable aspects are not likely to be underestimated and favorable aspects are not likely to be overestimated. If DOE excludes features and processes from the analysis, it should address the potential for the repository performance to be overestimated by their exclusion.

3. Model Abstraction

It is not clear that assumptions are used consistently throughout the performance assessment. Assumptions should be applied consistently to the extent practicable and the potential influence on the performance assessment of any known inconsistencies present should be addressed.

Performance assessments of Yucca Mountain will include abstracted models to represent components of the repository system; they also include models of different spatial scales. Differences in scale and the degree of abstraction may introduce unavoidable inconsistencies in the assumptions. However, assumptions -- including parameter values, parameter ranges, boundary conditions, and initial conditions -- should be consistently applied to different models within the performance assessment, to the extent practicable.

A number of illustrative examples of potential issues related to model abstraction have been identified. First, from our analysis, it is not clear that the geohydrologic properties used to calculate temperature are consistent with the geohydrologic properties used to calculate unsaturated flow. Properties should be consistently applied throughout the model. Second, although there are parameters that could influence the biosphere dose conversion factors, the biosphere dose conversion factors appear to be randomly sampled and are independent of these parameters (e.g., precipitation). Finally, correlations and dependencies should be maintained throughout the performance assessment model. An example relates to temperature increases caused by decay heat; these are calculated using two mountain-scale models (3-D conduction and 2-D Equivalent Continuum Model [ECM]) and three drift scale models (2-D dual permeability model, 3-D thermal conduction model, 3-D ECM for thermohydrology). It is unclear how DOE maintains consistency with changes in the spatial scale, the dimensionality or the processes.

4. Documentation of Assumptions

It is not clear that the approaches used to abstract models are adequately documented. DOE should document assumptions for the models within the performance assessment, such that there are no significant implicit or unstated assumptions.

The current DOE approach uses abstractions of detailed models (e.g., unsaturated and saturated flow and radionuclide transport) in the performance assessment. Assumptions arise from the derivation of the abstracted model and are carried over from the detailed model upon which the abstracted model is based. Each of these assumptions should be addressed to document the applicability and limitations in the abstracted model. The relationship of an abstracted model to the detailed model from which it is derived should be clearly explained for each abstraction in the performance assessment documentation.

5. Transparency and Traceability of Analysis

The documentation of the performance assessment results should allow the contribution of each alternative conceptual model to be evaluated.

Transparency and traceability of the performance assessment depend, in part, on the treatment of alternative conceptual models. DOE has suggested that the performance assessment could combine multiple alternative conceptual models within a single calculation. Transparency and traceability of the performance assessment could be compromised if such a calculation were presented without the disaggregated results. If DOE combines multiple conceptual models into a single calculation, DOE should provide disaggregated results to maintain transparency and traceability.

Engineered System Performance

6. Container Life

NRC is concerned that the performance assessment may include inadequately justified assumptions about waste package performance that could lead to an overoptimistic estimate of performance. The uncertainty in waste package performance arising from the limited amount of data on the behavior of waste package materials, the degree of confidence in projecting the behavior over long time periods, or the uncertainty in near-field environmental conditions, does not appear to be fully captured by the modeling. Justification should be provided for the modeling of waste package performance and the extent to which the modeling has adequately represented the uncertainty.

The long-term integrity of the waste package appears to be a significant contributor to repository performance. Therefore, DOE should address the uncertainties in the conceptual models and data used to predict the performance of waste package materials over thousands of years.

DOE has conducted tests which indicate that alloy C-22 may be susceptible to stress corrosion cracking (SCC) in the experimental environments. However, literature data and testing performed on less SCC resistant alloys such as alloy 825 indicate that alloy C-22 is unlikely to suffer stress corrosion cracking under the environmental conditions used in DOE's tests. DOE should consider reevaluating its testing methodology and perform confirmatory testing to determine whether alloy C-22, in fact, is susceptible to SCC in the environments tested by DOE.

If alloy C-22 is susceptible to SCC in expected repository conditions, DOE should consider SCC as a viable waste package failure mode -- unless it can demonstrate that SCC leading to waste package failure during the compliance period is not expected. Previous DOE tests on alloy C-22 do not appear to provide a sufficient basis to preclude SCC from being considered as a viable mode of failure. DOE's tests indicating SCC of alloy C-22 did not permit the measurement of the functional relationship between crack velocity and stress intensity factor, so they do not provide a sufficient basis for concluding that cracks will be arrested below those stress intensity factors used in the

tests. Also, DOE has indicated that it believes that SCC of alloy C-22 is unlikely to lead to waste package failure in the current design, since the critical flaw size required to fracture the container is believed to be of the order of the thickness of the inner overpack. However, the measured crack velocities were relatively high and may be sufficient to propagate through the thickness of the inner overpack at stress intensities significantly lower than those used in DOE's tests. Therefore, the critical flaw size leading to waste package fracturing in thousands of years, may be significantly smaller than those estimated by DOE.

7. Role of Rockfall in Assessing Waste Package Lifetime

Neglecting early failures could lead to an overestimation in the effectiveness of engineered barriers. DOE should consider the potential for these early failures in performance assessments for Yucca Mountain.

The long-term integrity of the waste package appears to be a significant contributor to DOE's performance assessment. Neglecting processes and events that could lead to early failures is likely to result in overoptimistic estimates of repository performance. Seismic events of sufficient magnitude to introduce rockfall in the repository are expected to occur. Rockfall has the potential to increase the number of early waste package failures, particularly if backfill is absent. The relative importance of these early failures increases as the expected lifetime of the waste package increases and becomes greater when assumptions on waste package behavior lead to estimates where waste packages do not fail from corrosion within the compliance period.

8. Effectiveness of Engineered Barriers in the Event of Volcanic Activity

NRC is concerned that the current analyses of volcanic activity are based on a limited consideration of waste package failure modes and do not include the full range of physical conditions representative of basaltic volcanic eruptions characteristic of the Yucca Mountain region. DOE should consider the range of physical conditions representative of characteristic volcanic eruptions and potentially significant waste package failure modes in its performance assessment of igneous activity, when determining the importance of igneous activity to overall repository performance.

Lathrop Wells, Little Peak, and Black Peak likely sustained large convective eruption columns that transported material tens of kilometers away and had subsurface conduits tens of meters in diameter. This type of eruption is commonly referred to as violent strombolian. A violent strombolian eruption at Yucca Mountain could involve dense magma (1000-2600 kg/m^3) at high temperatures (1000-1100 °C) impacting waste packages at velocities of 10-100 m/s for days to weeks. Such an eruption could involve failure modes other than corrosion and high-temperature deformation, the only assumed failure mechanisms in the current DOE analysis, and result in an energetic ash plume that could transport waste significant distances.

Natural System Performance

9. Neptunium Solubilities

NRC is concerned that the current estimates of neptunium concentration limits in the TSPA-VA calculations are unsupported, because there is insufficient evidence to discount earlier measurements of higher solubilities as being unrepresentative of the expected repository environment.

NRC guidance on radionuclide solubility in groundwater recommends that 'solubilities' should be approached from both oversaturation and undersaturation. This guidance has been followed by DOE contractors producing neptunium concentrations several orders of magnitude greater than those from spent fuel immersion tests, drip tests, and flow-through tests involving spent fuel. A possible explanation for the discrepancy was discussed at the March technical exchange. It is proposed that the neptunium solid in the solubility studies is metastable, and would not be expected in the repository environment. This postulate is based on thermodynamic calculations involving extremely uncertain values and is insufficient to justify the lower limits on neptunium concentrations. In earlier performance assessments for a Yucca Mountain repository, neptunium has been shown to be one of the main contributors to dose. The current estimates of the neptunium concentration limits by NRC and DOE differ by one order of magnitude. If the current DOE estimates for the neptunium concentration limits are incorrect, they could lead to an overoptimistic estimate of repository performance.

10. Matrix Diffusion

NRC has a number of concerns with the DOE approach to include matrix diffusion into its unsaturated zone (UZ) and saturated zone (SZ) flow and transport models. These concerns relate to assumptions that could lead to overoptimistic estimates of repository performance.

DOE's approaches to UZ and SZ matrix diffusion include assumptions that could result in substantial delays in the arrival of contamination at the receptor location and an overoptimistic estimate of repository performance. DOE should clearly document the technical basis for its assumptions (e.g., distribution of mean effective porosity in the SZ and estimate of the transfer term for fracture-matrix exchange in the dual permeability model for UZ transport). The staff has concerns that the residence time transfer function (UZ transport) for the dual continuum model is overestimated, because assuming an immobile reservoir neglects the transfer function accounting for particles moving from the matrix to the fracture. The staff is also concerned that DOE's use of the 50-percent relative solute concentration arrival times to derive the range of effective porosities has inherent non-conservatism that could be avoided by basing the effective porosity approach on the earliest solute arrival times (e.g., 5-percent relative solute concentration). Finally, it appears that, although the matrix diffusion behavior is different for each solute, DOE is using the same effective porosity for each solute. If DOE intends to neglect this variation in solute behavior, it should use the effective porosity of the least diffusive solute likely to influence performance.

11. Saturated Zone Transport

DOE's approach to modeling radionuclide transport in the saturated zone, as described in the March 1998 technical exchange, uses three-dimensional flow and transport models. The modeling does not appear to convey adequately the uncertainty associated with the limited SZ data on which it is based. DOE should consider the uncertainty introduced by limited field data when modeling SZ transport and the resultant effects on the output.

There is limited data for the saturated zone along the groundwater pathway south of the repository, particularly in the region from wells J-12 and JF-3 to an assumed receptor location 20 km from the repository. This makes any estimate of maximum radionuclide concentration highly uncertain. Uncertainty in SZ transport associated with limited data can be addressed in different ways, such as collecting additional data or using a modeling approach that adequately represents the uncertainty.

12. Radionuclide Retardation

The staff considers that DOE's assumed sorption coefficients (K_ds) and probability distribution functions (PDFs) for retardation may lead to overoptimistic estimates of repository performance. The technical bases for these assumptions is incomplete. Documentation of the performance assessment should include the technical bases for assumed K_ds and PDFs for retardation used in the analyses.

The transport of radionuclides and, consequently, the results of the performance assessment can be strongly influenced by retardation values used in the modeling. The performance assessment documentation should include a discussion of the technical bases for both K_d values and PDFs for retardation that are used in the analysis. The technical bases that DOE is using to support its choice of K_ds and PDFs for retardation for some radionuclides is not complete. In particular, DOE should support its use of analogs for developing K_ds for radionuclides such as niobium, samarium, actinium, and protactinium. DOE also should consider either addressing correlations in K_ds or documenting how its results may be influenced by the omission of these correlations.

13. Treatment of Colloids

The current DOE models for colloid transport have the potential to underpredict colloid transport and lead to overoptimistic estimates of repository performance. DOE should evaluate the influence on performance of its assumption that radionuclides experience reversible sorption on groundwater colloids.

The results of colloidal transport models that use low values of the plutonium colloid partitioning coefficient (K_c) would underpredict radionuclide transport, if irreversible sorption processes such as precipitation are dominant or waste form colloids survive without dissolution during transport. Models presented for colloid transport in the engineered barrier system, the unsaturated zone, and the saturated zone for TSPA-VA all assume that radionuclides experience reversible sorption on groundwater colloids. These models are based on work performed at Los Alamos National Laboratory, which

is empirical in nature and has only a limited mechanistic basis. DOE should address the potential for its current models to underpredict colloid transport. If the assumption of reversible sorption may lead to an overoptimistic estimate of repository performance, then improvements in the mechanistic basis for the assumptions of colloidal stability could become necessary.

Procedural Issues

14. Basis for Assigning Probabilities to Corrosion Potential Values

The documentation of the performance assessment should document how the results of expert elicitations are incorporated into the analysis. Major assumptions by the experts also should be identified, so that limitations on the results are clearly understood.

Based on the results of an expert elicitation, DOE has assigned probability percentages to three different values of corrosion potential for the corrosion resistant material under dripping conditions. The physical bases for assigning probabilities to each of these potential values have not been documented as part of the expert elicitation. The justification for assigning probabilities to the corrosion potential should be included in the documentation of the performance assessment.

15. Uncertainty in the Results of Expert Elicitation

DOE should evaluate whether the use of point values adequately conveys the results of the expert elicitation and the associated uncertainty.

Based on the results of an expert elicitation, DOE has assigned point values to three different values of corrosion potential for the corrosion-resistant material under dripping conditions. This approach does not allow the explicit assessment of the influence of changing near-field environmental conditions and impedes DOE's ability to adequately propagate uncertainty in the near-field environmental conditions through the performance assessment.

16. Development of Expert Elicitation Results for Use in Performance Assessment

The process of eliciting expert opinion on issues related to performance assessment should provide the experts with timely information on how their results are expected to be used in the performance assessment.

The Probabilistic Seismic Hazard Analysis could have been improved by providing the experts, at the start of the elicitation, with a clearer understanding that their input would also be used for post-closure performance assessment. DOE should have a clear understanding of the expected use of the elicited expert judgments before convening the panels, so that (1) the right expertise is available on the panel to minimize the potential for only one or two experts being capable of responding to a question, (2) post-processing of the elicited judgment is avoided or minimized, and (3) there is appropriate integration between panels (e.g., the results from the near-field panels are used to develop the initial and boundary conditions for the waste package corrosion panels). If post-processing of the elicited judgment is required, it should be clearly documented.