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U.S. DEPARTMENT OF ENERGY (DOE) REVIEW OF U.S. NUCLEAR REGULATORY COMMISSION'S (NRC) EVOLUTION OF THE NEAR-FIELD ENVIRONMENT ISSUE RESOLUTION STATUS REPORT, REVISION 2

DOE has reviewed Revision 2 of the Issue Resolution Status Report (IRSR) on the Key Technical Issue of Evolution of the Near-Field Environment. The enclosed comments resulting from that review are directed primarily at the acceptance criteria for the subissues associated with evolution of the near-field environment and related discussions of the technical bases supporting those criteria.

In general, the DOE agrees with the risk-informed, performance-based approach that the NRC staff has adopted in its development of the proposed 10 CFR Part 63. However, we are concerned that some of the discussions in the subject IRSR contain implicit or explicit requirements beyond those in the acceptance criteria. A number of these requirements appear to be more prescriptive than is the intent of the performance-based proposed 10 CFR Part 63. They appear to remove the flexibility contained in the proposed regulations and are not clearly linked to repository performance. These concerns are noted in our comments.

DOE appreciates the opportunity to review the IRSRs and provide comments for your consideration. We request that our comments be considered in the preparation of the next revision of the IRSR.

If you or your staff have any questions regarding our comments, please contact Deborah Barr at (702) 794-1749 or Carol Hanlon at (702) 794-1324.

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Enclosure:
Comments on Issue Resolution Status
Report, Revision 2 Key Technical Issue:
Evolution of the Near-Field Environment

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# COMMENTS ON ISSUE RESOLUTION STATUS REPORT, REVISION 2, KEY TECHNICAL ISSUE: EVOLUTION OF THE NEAR-FIELD ENVIRONMENT

## Comments

1. Section 3.2.1, page 10: The Issue Resolution Status Report (IRSR) notes the potential for significant impacts in performance due to concrete degradation. This issue is minimized by the small amount of concrete planned for use in designs DOE is currently considering, a fact that is not recognized in the IRSR discussion (though the potential impact of reduction in planned use of concrete is discussed elsewhere in the IRSR). A discussion of cementitious materials on pages 38 and 39 also makes no mention of the much smaller use of cement in the emplacement drifts in the designs currently under consideration. DOE suggests that correction or clarification of the statement be provided.

   NOTE: Under designs currently under consideration, there will still be concrete in the access and ventilation drifts and ventilation shafts. These may contain a very large amount of concrete. The migration of alkaline plumes may still be an issue relative to these parts of the design. In addition, the design usage of cementitious grout for rockbolts in ground support of potential emplacement drifts has not yet been demonstrated to be of negligible potential for impact to waste isolation capabilities of the system. DOE is evaluating the potential for chemical effects of these cementitious materials to impact repository performance.

2. Section 4.1.1, page 30: "Review method" notes that DOE should provide sound bases for inclusion or exclusion of certain observed phenomena in its conceptual models. However, the acceptance criteria that follow are phrased in terms that imply a detailed analysis of thermal-hydrologic-chemical (THC) phenomena is needed, regardless of the effects of these phenomena on performance. Suggested revisions:

   (a) DOE suggests that Criterion 1 be revised to state: "Available data...were considered *to the extent needed to demonstrate the impact of these effects on repository performance. DOE may choose to exclude a given coupled THC process from detailed analysis if it can demonstrate the effect of the process is bounded or is insignificant to performance.*"

   (b) DOE suggests that wording at the end of Criteria 2 and 3 be revised to state: "...coupled processes that may affect seepage and flow, *to the extent needed to demonstrate the impact of these processes on repository performance. DOE may choose to exclude a given coupled THC process from detailed analysis if it can demonstrate the effect of the process is bounded or is insignificant to performance.*"

3. Section 4.1.1, page 31: DOE suggests the following changes:

   (a) The sentence beginning with "In addition" and ending with "total system performance assessment (TSPA)" should be revised to add the following phrase at the end of the sentence: "...*to the extent they have a significant impact on repository performance.*"

(b) DOE suggests that Criterion 3 be revised after "seepage and flow" by addition of "*to the extent needed to demonstrate the impact of these processes on repository performance. DOE may choose to exclude a given coupled THC process from detailed analysis if it can demonstrate the effect of the process is bounded or is insignificant to performance.*"

4. Section 4.1.1, page 32: DOE suggests that the first sentence in Criterion 1 be modified to allow DOE to choose to exclude a given process from detailed analysis if it can demonstrate the effect of the process is bounded or is insignificant to performance.

5. Section 4.1.1, page 34: DOE suggests that Criterion 2 be revised to state: "Models reasonably account for known temporal and spatial variations in conditions affecting coupled THC effects on seepage and flow, *to the extent needed to demonstrate the impact of these processes on repository performance. DOE may choose to exclude specific temporal/spatial variations in conditions from detailed analysis if it can demonstrate that such variations are bounded or are insignificant to performance.*"

6. Section 4.1.2.1, page 38: The IRSR states that "the effects of chemistry on flow are commonly neglected in TH simulations. Extensive development of heat pipe effects and refluxing at elevated temperatures could cause changes in porosity, permeability, and solution composition over regulatory time frames of thousands of years (e.g., Hardin, 1998)."

   The effects of chemistry are addressed in thermal-hydrologic-chemical (THC) simulations, not in thermal-hydrologic (TH) simulations. In addition, because the repository configuration and related thermal field has changed significantly, the design under DOE consideration will not likely lead to heat pipes. DOE suggests that the paragraph on heat pipes be revised to reflect this information.

7. SCA Question 30, page 97: The IRSR states that Total System Performance Assessment – Viability Assessment (TSPA-VA) did not address effects of salt formation and increased pH as a result of interaction with concrete on waste package corrosion rates.

   This statement is not accurate. With regard to salt formation, the environments on which the waste package corrosion models were based included a highly saline, aggressive salt solution that is taken as representative of water during periods of salt formation. This environment is actually imposed for longer time than would be expected (see Chapter 5, Section 5.11.1, fifth bulleted paragraph, CRWMS M&O 1998). The base-case corrosion rates utilized were for concentrated salt solutions without consideration of evolution to more dilute solutions with later dripping flux (see Chapter 5, Section 5.13.5, third paragraph, CRWMS M&O 1998).

   The second aspect of the statement suggests that some of the sensitivity analyses for the TSPA may have been overlooked by the NRC. Explicit sensitivity analyses were conducted to evaluate the effects of the concrete-modified water on the waste package evolution in the TSPA-VA (Volume 3, Sections 5.3.2 and 5.4.4, DOE 1998). Abstracted models for the in-drift geochemical environment in the TSPA-Site Recommendation (SR) are incorporating changes to water composition during salt/precipitate-dominated periods. Whereas the TSPA-VA used a

broad, stochastic distribution for corrosion rates based on expert judgment and test data from aggressive environments, corrosion dependencies on specific compositional parameters are being constrained for TSPA-SR, incorporating the available long-term corrosion test data. In addition, the new waste package design is expected to be more robust than the VA design (i.e. less sensitive to high pH and the relatively benign salts expected).

DOE suggests that the descriptions identified be revised to reflect the information contained in this comment.

8. Section 5.4.1, page 105, paragraphs 2 and 3: The IRSR states that data and models used in TSPA-VA to calculate the quantity and chemistry of water dripping onto waste packages under thermally altered conditions were inadequate. The IRSR also states that current DOE testing and modeling plans are not sufficient to resolve the issue prior to license application (LA) submittal. In addition, it states that systematic air permeability measurements conducted in horizontal boreholes could provide needed data on variability and heterogeneity in rock properties. Coupled THC processes that effect seepage and flow were not considered explicitly.

   DOE recognizes the limitations of the models for water chemistry incorporated into the TSPA-VA and the need for improvements in this area. Mechanistic and bounding models are being developed for the quantity and chemistry of water entering the drift as seepage and of the water contacting the drip shield and waste package. In the analyses for the TSPA-SR, DOE has based the abstracted models for water and gas entering the potential emplacement drifts on the results of fully-coupled THC process models for the evolution of water and gas in the geosphere. These process models are summarized in the Unsaturated Zone Flow and Transport (UZFT) Process Model Report (PMR). The UZFT PMR includes kinetic representations of the fluid-rock reaction and constraints from field testing and validation exercises based on the thermal testing being conducted at the site. In addition, the abstracted models for seepage (i.e., liquid flux into the drift) are incorporating the effects of the thermal perturbation. DOE believes that the suite of field tests (including the Exploratory Studies Facility (ESF) permeability/hydrologic tests, the drift scale test (DST), the single-heater test (SHT), the large-block test, the cross-over alcove tests, and the cross drift thermal tests) are designed to provide sufficient permeability and thermal data/analyses for LA models, and will continue to provide confirmatory data following submittal of the LA.

   DOE suggests that the descriptions identified be revised to reflect the information contained in this comment.

9. Section 5.4.1.1, page 107, Criterion 3: The IRSR states that DOE did not consider the potential adverse consequences from the assumption that the concrete liner collapses early, particularly the potential substantial degradation of waste package performance from high-pH waters that have traversed the concrete liner. It adds that DOE did not collect sufficient data on the quantity and reactivity of concrete used in the drift that may affect flow in the UZ. Also, it states that DOE should continue studies of mineral precipitation and dissolution, focusing on potential formation of durable permeability heterogeneities and resulting effects on flow and seepage into and from the drifts. These properties should be used in abstractions.

As stated in the response above covering the comment on page 97 of the IRSR (see Comment 7), the first part of this comment was addressed in the TSPA-VA. Explicit sensitivity analyses were conducted to evaluate the effects of the concrete-modified water (highly alkaline for 10,000 years) on the waste package evolution in the TSPA-VA (Volume 3, Sections 5.3.2 and 5.4.4, DOE 1998). The scenario described in the NRC comment was the basis for the concrete-modified water case that was evaluated in the TSPA-VA Analyses Technical Basis Document, (Chapter 4, Sections 4.6.2.2.1.1 and 4.6.3, and Section 4.7.2 second and third paragraphs, CRWMS M&O 1998). Scoping studies of mineral precipitation and dissolution have been conducted. Because of kinetic limitations, preliminary simulations of host rock behavior indicate minor changes in fracture properties, except for the possibility that precipitates can accumulate where boiling occurs. The current design use of cementitious materials in the potential emplacement drifts is much less than for the VA design. Drift-scale coupled THC process modeling is addressing durable property changes due to mineral precipitation and dissolution, and their potential effects on seepage around drifts. In addition, these coupled THC process models are used to calculate the chemistry of water and gas that could flow into potential emplacement drifts.

DOE suggests that the descriptions identified be revised to reflect the information contained in this comment.

10. Section 5.4.1.2, page 109, Criterion 3: The IRSR states that DOE did not attempt to abstract the effects of concrete-tuff interactions on seepage and flow. It also notes proposed changes may render such interactions no longer pertinent.

    Because of changes to the design that remove concrete from the emplacement drifts, this process is of much-reduced potential import around emplacement drifts. The design concepts currently under consideration include possible use of cementitious grout for rockbolts in the back of the emplacement drifts. Even this usage is expected to be of limited extent, and DOE is evaluating the specific cementitious materials within the context of the physical and chemical environment model for potential to generate alkaline fluids. This is summarized in the EBS Process Model Report. DOE does not currently plan to perform reactive transport modeling of alkaline plumes emanating from concrete potentially used outside of emplacement drifts to constrain alteration of the geosphere transport pathways.

    DOE suggests that the NRC consider revising the descriptions identified to reflect the information contained in this comment.

11. Section 5.4.1.3, page 111, Criterion 3: The IRSR states that important processes associated with the precipitation and dissolution of calcite and other minerals in fractures were omitted. For example, the GIMRT code is unable to treat phenomena associated with boiling. The discussion states that these issues should be examined using multiphase coupled models.

    DOE does not plan to use the GIMRT code to describe the near-field or in-drift environments. Multi-phase codes have been developed for this purpose. Modeling of coupled THC processes for license application design selection, drift-scale seepage models, the DST, the SHT, and investigation of sealing by calcite, includes coupled non-isothermal, multiphase flow associated with boiling and vapor transport in dual-permeability systems. DOE is considering various minerals, including calcite, aluminosililicates, silica, and sulfates.

DOE suggests that the text be revised to reflect the information contained in this comment.

12. Section 5.4.1.5. page 112, Criterion 1: "The general approach taken in TSPA-VA was to decouple system behavior according to type of process. This assumption of weak feedback among processes is considered inadequate when applied to THC-induced changes in the repository flow system, which are characterized by strong coupling between thermal-hydrology effects, multi-component chemistry, and rock-water interaction."

    The decoupling of processes in the TSPA-VA was supplemented by some consideration of the processes that should dominate the interactions in construction of the models. For example, although the incoming gas composition model was not coupled to the TH processes directly, it was formulated using the dominant parameters resulting from the TH process models. This simplistic approach is being supplanted with more comprehensive reactive transport models that directly couple some of the major THC interactions. However, in the potential emplacement drift environment, the compositional complexity still precludes as comprehensively coupled an approach as is being applied to the geosphere for the TSPA-SR. In this case, the approach has been to directly incorporate more compositionally comprehensive models that cover the major chemical changes that may occur. DOE is using this loosely coupled approach with models developed for the hydrologic flow pathways through the drift to provide a more representative evolution of the environment than was derived in the TSPA-VA.

    DOE believes that THC-induced changes in the repository flow system are minor. DOE expects to demonstrate that combinations of low thermal loading and relatively large values for fracture porosity that apply to Yucca Mountain result in changes in bulk permeability that are negligible for predicting thermal-hydrologic behavior. This is based on the preliminary results of coupled THC models. We may reach similar conclusions for THM effects. Thus, with low thermal loading, it is not a foregone conclusion that THC/THM effects will be important to performance. With regard to thermal-chemical processes, the emphasis for the Site Recommendation (SR)/LA design concept is on the chemistry of the water that reaches the drip shield and waste package.

    DOE suggests that the text be revised to reflect the information contained in this comment.

13. Section 5.4.1.5. page 112, Criterion 1: "The approach that DOE used for the VA did not include a formal screening process for features, events, and processes (FEP). As a result, many important design features, physical phenomena, and couplings were not evaluated."

    A formal FEPs analysis is being performed for each aspect of the potential repository system for the TSPA-SR.

14. Section 5.4.1.6, page 115, Criterion 3: "The results from the near-field/altered zone expert elicitation were not used in the near-field seepage abstraction. ... Based on recent presentations, it is not clear that recommendations from the near-field/altered zone expert elicitation on reducing uncertainties are being considered."

Recommendations from the near-field/altered zone expert elicitation were not used directly because the expert elicitation recommendations were already bounded by the near-field seepage abstraction. DOE is addressing some uncertainties with regard to host rock behavior by bounding the responses to heating. Other uncertainties may be addressed by limited additional testing. The design concepts currently under consideration make bounding arguments more attractive for certain aspects of near-field performance. In particular, the drip shield may be treated as a barrier that separates the waste package from uncertain effects of heating in the host rock and the in-drift environment. It may continue to perform even after cracks and other penetrations form, but it may not contribute to predicted performance after the thermal period.

DOE suggests that the text be revised to reflect the information contained in this comment.

15. Section 5.4.2, page 116, paragraph 1: The IRSR concludes "it is unclear whether DOE will be able to acquire sufficient data applicable to repository conditions to demonstrate compliance with NRC requirements. The bulk of the long-term data used in TSPA-VA may not be applicable to environmental conditions at Yucca Mountain, particularly with regard to water chemistry."

    The long-term corrosion tests underway at the Lawrence Livermore National Laboratory (LLNL) span a broad range of water chemistry (pH, ionic strength) and exposure conditions (submerged, half submerged, and exposed to vapor only). Mechanistic studies using extremely precise measurements of very low corrosion rates are also expected to provide credibility. In the TSPA-SR analyses, the corrosion models and associated parameters for important degradation processes of the waste package and drip shield materials are being based on the long-term and short-term corrosion testing data for a range of exposure conditions (especially water chemistry) that are expected in the repository. The TSPA-SR waste package performance analyses are expected to capture the effect of the repository-specific environments to the extent the data and information is available at the time of the analysis, including temporal and spatial variations. DOE believes that data collection and model development will continue to improve the models and enhance modeling confidence.

    DOE suggests that the text be revised to reflect the information contained in this comment.

16. Section 5.4.2.1, page 117, Criteria 2: The IRSR states that DOE's near-field geochemical environment model focused on the central part of the repository, but effects of certain coupled processes may be most important on the margins of the emplacement zone. Also, it states that DOE should justify neglecting processes at the margin of the emplacement zone. It adds that potential episodic seepage events should also be considered. It also mentions that recent interactions indicate DOE is attempting to address this criterion.

    The TH analyses used for the near-field geochemical environment (NFGE) analyses for TSPA-VA indicated that changes to air mass fraction and gas flux were greatest in the central portion of the potential repository compared to the edge (Chapter 4, Figures 4-16 through 4-19, CRWMS M&O 1998). In the NFGE, evaluation of the potential for oxygen depletion and reduced conditions concluded that such conditions are not feasible for this central portion, and higher oxygen flux nearer the edges makes that conclusion even stronger for those regions. For the TSPA-SR, the gas composition entering the drift is being constrained by fully-coupled THC models, and the seepage models are dependent on the thermal perturbation. Therefore, a more

robust description of the spatial and time varying nature of these aspects should be possible for the LA. The water compositions that evolve in the potential drifts are being tied to the temporal changes of the temperature and relative humidity, which vary spatially.

DOE suggests that the text be revised to reflect the information contained in this comment.

17. Section 5.4.2.1, page 118, Criterion 3, paragraph 1: The IRSR states that the DOE base case does not include the effect of seepage water interacting with concrete drift lining. It cites one-year experiments at LLNL as showing that carbon steel in concentrated pH (9.7), J-13 water does not show high aspect ratio pitting corrosion. The IRSR considers the LLNL results to be inadequate to disprove potential for enhanced pitting at alkaline pH.

    Because of changes to the design concepts that remove concrete from the emplacement drifts, there is reduced potential for this process around emplacement drifts. The designs currently under consideration include possible use of cementitious grout for rockbolts in the back of the emplacement drifts. Even this usage is expected to be of limited extent, and DOE is evaluating the specific cementitious materials within the context of the physical and chemical environment model for potential to generate alkaline fluids.

    DOE suggests that the text be revised to reflect the information contained in this comment.

18. Section 5.4.2.3, page 122, Criterion 1: The IRSR states that salt formation was not used in the TSPA-VA analyses, and the current (stochastic) waste package degradation model is not yet capable of modeling the specific chemistry of the corrosion-resistant material localized corrosion.

    In the TSPA-VA analysis, potential effects of salt formation and water chemistry on waste package degradation were captured implicitly by sampling, on a local area scale (referred to as patch), relevant corrosion initiation thresholds and corrosion rate parameters. As discussed in the response to the comment on IRSR page 116 (Comment 15), models in the TSPA-SR analysis for various corrosion initiation thresholds are expected to be based more on relevant mechanistic processes. For example, the critical relative humidity to form a water film on the waste package and drip shield is being based on testing data and detailed analysis of water chemistry evolution on the waste package and drip shield. The crevice corrosion initiation threshold is being based on corrosion potentials that are a function of chemistry of the contacting solution. The waste package degradation model is being improved to accommodate the mechanistic models. The waste package performance analysis is using those water chemistry-based corrosion parameters in conjunction with exposure condition inputs that vary temporally and spatially in the repository.

    DOE suggests that the text be revised or clarified to reflect the information contained in this comment.

19. Section 5.4.2.3, page 122, Criterion 2: The IRSR states that the Near-Field/Altered-Zone Models Report (Hardin, 1998) notes numerous explicit statements of model inadequacy.

    This statement is not supported by the cited text. The text in Hardin (1998) indicates that although the starting composition of some water may not be well represented by J-13 water, "the errors and uncertainties in the starting compositions tend to be overwhelmed by the effect of rock-water interaction." Although DOE expects that this complex area will undergo improvements into the performance confirmation period, a number of the model improvements are represented by the fully-coupled THC models for water-rock reaction in the geosphere. In addition, evolution of in-drift chemistry is being improved to specifically account for evaporative concentration and formation of brines. All models retain some inaccuracy. Confidence in many aspects of performance models is being improved by validation testing.

    DOE suggests that the text be revised or clarified to reflect the information contained in this comment.

20. Section 5.4.3.1, page 131, Criterion 5: The IRSR states that "It is not clear that DOE will pursue any further work on microbial processes in the near field. Neglecting the potential impact of microbial processes on radionuclide release will require justification."

    Analyses of potential microbial growth are being performed for the revised design for TSPA-SR. Also, testing of the microbial growth model against laboratory experimental data is being performed and documented as part of model validation/testing in order to further assess the utility of the microbial growth model. The analyses for growth of microbial communities provide the source terms for models of microbiologically induced corrosion in the TSPA corrosion models and for potential inclusion of microbial colloids in the transport models.

    DOE suggests that the text be revised to reflect the information contained in this comment.

**References**

Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O), 1998, *Total System Performance Assessment—Viability Assessment (TSPA-VA) Analyses Technical Basis Document*, B00000000-01717-4301 (00001 through 00011 for Chapters 1 through 11), Rev. 01, Las Vegas, Nevada. ACC: MOL.19981008.0001-0011.

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