U.S. NUCLEAR REGULATORY COMMISSION, OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, REVIEW OF THE U.S. DEPARTMENT OF ENERGY AGREEMENT RESPONSES RELATED TO THE POTENTIAL GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, NEVADA: KEY TECHNICAL ISSUE AGREEMENTS TO TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION 2.02, COMMENT 59, ADDITIONAL INFORMATION NEED, WITH REFERENCE TO RELATED AGREEMENTS THERMAL EFFECTS ON FLOW 2.05 AND GENERAL 1.01, COMMENTS 5 AND 16

1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) issue-resolution goal during the prelicensing period is to identify and resolve, if possible, technical issues prior to receipt of a License Application. NRC staff resolution of an issue during prelicensing does not preclude the raising of related issues during the licensing proceedings. Also, and equally important, NRC resolution of an issue during prelicensing does not prejudge NRC staff's evaluation of the issue during the licensing review. NRC staff considers an issue resolved during prelicensing when it has no further questions nor comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments about a previously resolved issue.

This review addresses additional information DOE supplied in its December 22, 2006, letter (Williams, 2006) to the Director, Division of High-Level Waste Repository Safety, NRC, which responded to a staff Additional Information Need (AIN) for Key Technical Issue (KTI) Total System Performance Assessment and Integration (TSPAI) 2.02, Comment 59 (Kokajko, 2005a). This agreement was originally made between DOE and NRC during a Technical Exchange and Management Meeting (Reamer, 2001) and relates to the features, events, and processes (FEP) of repository-scale convection and condensation that were excluded from DOE performance assessments. DOE submitted a report (Bechtel SAIC Company, LLC, 2004a) to satisfy the information needs of this, and other agreements.

In Williams (2006), DOE notes that the technical issues of TSPAI 2.02, Comment 59, are related to those discussed in agreements Thermal Effects on Flow (TEF) 2.05 and General (GEN) 1.01, Comments 5 and 16. Whereas TSPAI 2.02, Comment 59, is concerned with the choice of excluding or including the FEP of repository-scale convection and condensation in performance assessments, TEF 2.05 and GEN 1.01, Comments 5 and 16, are concerned with model abstraction of included FEPs in the area of drift-scale and repository-scale convection and condensation. NRC considers TEF 2.05 and GEN 1.01, Comments 5 and 16, closed (Kokajko, 2005b). Because repository-scale convection and condensation processes are now included in the performance assessment, this review includes reference to NRC's comments on TEF 2.05 and GEN 1.01, Comments 5 and 16.

2.0 WORDING OF THE AGREEMENT

TSPAI 2.02, Comment 59

The wording covering all comments contained within Agreement TSPAI 2.02 is:

> "Provide the technical basis for the screening argument, as summarized in Attachment

2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J–1, J–2, J–3, J–4, J–7, J–8, J–9, J–10, J–11, J–12, J–13, J–14, J–15, J–17, J–20, J–21, J–22, J–23, J–24, J–25, J–26, and J–27.

DOE will provide the technical basis for the screening argument, as summarized in Attachment 2, for the highlighted FEP's. The technical basis will be provided in the referenced FEPs AMR and will be provided to the NRC in FY03."

The specific wording for Comment 59 is:

"2.1.08.04.00 (Cold Traps) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001b [2001, herein]). Emplacement of waste in the drifts creates thermal gradients within the repository that may result in condensation forming on the roof of the drifts or elsewhere in the engineered barrier system, leading to enhanced dripping on the drip shields, waste packages, or exposed waste material. The DOE Multi-scale Thermohydrologic Model does not account for mass transport along the length of drifts. The only Multi-scale Thermohydrologic Model submodel that includes thermal hydrology (i.e., mass transport) is a cross section of a drift, so it accounts for potential condensation only along the radial axis. "

TSPAI 2.02, Comment 59, AIN

NRC comments for the AIN (Kokajko, 2005a) are:

"Repository-scale cold traps are excluded because the condensation is stated to occur on drift walls and, therefore, does not contact the engineered barrier system; thus, the possibility of water dripping on drip shield and invert is not considered in screening arguments. Unreleased documents on natural convection (Multiscale Thermohydrologic Model, Revision 02 and In-Drift Natural Convection and Condensation Model) need to be reviewed to evaluate arguments indicating that condensed water resulting from repository-scale cold traps does not contact the drip shield nor the invert. DOE should consider providing information in any potential License Application to support repository-scale cold trap screening arguments."

3.0 SIGNIFICANCE TO PERFORMANCE

3.1 Context of FEPs

The goal of scenario analysis is to ensure that no important aspect of the proposed high-level waste repository is overlooked in the evaluation of its safety. The scenario analysis process provides the basis for initial development and identification of aspects relevant to waste isolation. Scenario analysis identifies FEPs that could influence, directly or indirectly, dose risk to a reasonably maximally exposed individual from the proposed high-level waste repository. Documentation of the compendium of FEPs facilitates identification of aspects analyzed in the evaluation of repository safety and serves as a road map to the location of analyses and their conclusions. Screening arguments provide rationale for either further considering or not considering FEP's in the total system performance assessment. A well-implemented process for identification of these FEPs helps to ensure that relevant aspects of the proposed high-level waste repository and associated implications to the dose risk are evaluated.

3.2 Significance for Agreement TSPAI 2.02, Comment 59

In Travers (2003), NRC staff described the basis for risk-ranking the KTI agreements. Although TSPAI.2.02 was categorized overall as high risk-significant, based on the scope and content of the comments in these agreements, individual comments within TSPAI.2.02 have not been separately categorized within the significance framework. It can be noted that Comment 59 is linked to the amount and distribution of water in drifts, and, if release of radionuclides occurs, is directly linked to the rate of transport out of the engineered barrier system. In NRC (2004), the amount of water in drifts, seepage, is categorized as medium risk significant. Invert flow and transport is considered low risk significant.

4.0 EVALUATION AND COMMENT

4.1 Background

The DOE FEP designation and approach for approximating in-drift processes have evolved dramatically since the time the Comment 59 was written. The processes and models can be described briefly in the following manner. In-drift processes of convection and condensation will occur even under ambient conditions because of naturally occurring variations in temperature. Strong thermal perturbations caused by emplacement of waste packages will drive convection and condensation processes that may significantly alter temperature distributions and liquid flux in the drifts. Estimates of the location and amount of condensation in drifts depend directly on estimates of temperature distribution on the drift wall, drip shield, invert, and waste package. Porous media models, such as the Multiscale Thermohydrological Model (Bechtel SAIC Company, LLC, 2005a), are not designed to simulate gas-phase heat and mass transfer in large open spaces, but are able to simulate multiphase flow (e.g., gas and liquid phases) in the host rock. Computational fluid dynamics models solve the Navier-Stokes equation, which with the Boussinesq approximation and time-averaging, have commonly been used to simulate single-phase thermally driven flow in large open spaces.

At the time Comment 59 was written (see Reamer, 2001), DOE used a two-dimensional porous media model to simulate radial thermohydrological processes in the host rock and drifts. DOE did not use computational fluid dynamics models to simulate in-drift processes. Effective thermal conductivity and pseudo-permeability were used to approximate convective and radiative heat transfer and gas-phase flow above the drip shield. The waste package and drip shield were lumped together and used as a single-block heat source, thus precluding the possibility of simulating conditions underneath the drip shield. There were two excluded FEPs related to in-drift convection and condensation listed in CRWMS (2001): FEPs 2.1.08.04.00 (Cold Trap) and 2.1.08.14.00 (Condensation on Underside of Drip Shield).

When NRC issued Kokajko (2005a), DOE had developed computational fluid dynamics models. The details, however, were contained in an unreleased analysis model report. The cold trap FEP was split into two separate FEPs: 2.1.08.04.0A ["Condensation Forms on Roofs of Drifts (drift-scale cold traps)"] and 2.1.08.04.0B ["Condensation Forms at Repository Edges (repository-scale cold traps)"]. The former was included in performance assessments and the latter, FEP 2.1.08.04.0B, was excluded (Bechtel SAIC Company, LLC, 2004b, as noted in Williams, 2006).

Williams (2006) and enclosures (Bechtel SAIC Company, LLC, 2005a, 2005b) provide information on DOE's current approach for incorporating the effect of in-drift convection and condensation on the liquid-flux distribution along drifts. The computational fluid dynamics model provides estimates of condensation along the drifts to the performance assessment model. The porous media thermohydrological models provide estimates of in-drift temperature and host rock saturation to the performance assessment model. An abstraction of computational fluid dynamics model results is used to support a simple one-dimensional network model to estimate condensation flux along drifts, which is added to the seepage flux. Also, dispersion coefficients calculated from the computational fluid dynamics models are used in the Multiscale Thermohydrological Model to approximate the effect of axial convection on in-drift temperature and host rock saturation. Thus, the dispersion coefficients are calculated from three-dimensional gas-phase flow, and implemented in the porous media model as unidirectional axial flow. The repository-scale convection and condensation FEP 2.1.08.04.0B is now included in the performance assessment (Williams, 2006; Bechtel SAIC Company, LLC, 2004c, 2005b). Note that condensation on the underside of the drip shield, FEP 2.1.08.14.0A, remains excluded, based on its low consequence contribution (Bechtel SAIC Company, LLC, 2004c).

4.2 Agreement TSPAI 2.02, Comment 59, AIN

The wording of Agreement TSPAI 2.02, Comment 59, and the AIN, resolves down to the screening decisions for the three cold-trap related FEPs:

- FEP 2.1.08.04.0A: "Condensation Forms on Roofs of Drifts (drift-scale cold traps)." Included (Bechtel SAIC Company, LLC, 2004c).
- FEP 2.1.08.04.0B: "Condensation Forms at Repository Edges (repository-scale cold traps)." Included (Williams, 2006; Bechtel SAIC Company, LLC, 2004c).
- FEP 2.1.08.14.0A: "Condensation on the Underside of the Drip Shield." Excluded by low consequence (Bechtel SAIC Company, LLC, 2004c)

Williams (2006) stated that the screening decision for repository-scale convection and condensation, FEP 2.1.08.04.0B, changed from that reflected in Kokajko (2005a) and Bechtel SAIC Company, LLC (2004b). Condensation from repository-scale convection is now added to the seepage flux in performance assessments, and may contact the drip shield and waste package (Bechtel SAIC Company, LLC, 2005b). For both of the included FEPs, the NRC evaluation falls under TEF 2.05 and GEN 1.01, Comments 5 and 16. Comments related to these agreements are summarized and updated from Kokajko (2005b) in section 4.3.

The FEP for condensation on the underside of the drip shield was excluded in Bechtel SAIC Company, LLC (2004c) because of low consequence. Because the supporting documents were not publicly available, the basis for excluding dripping from underneath the drip shield was not transparent at the time Kokajko (2005a) was issued. Additional information was summarized in Williams (2006), which included two supporting documents as enclosures. The newly released documents are Bechtel SAIC Company, LLC (2005a, 2005b); both documents were said to be under further revision. The scenario of dripping from the underside of the drip shield requires evaporation from the invert beneath the drip shield, followed by condensation on the underside of the drip shield. Condensation on non-horizontal surfaces was stated to likely flow down the sides of the drip shield surface. Although the top of the drip shield may be the hottest location because of rising convective air flow, the possibility of dripping from the center of the intact drip shield onto the waste package was considered. Dripping onto the waste package was said to be of low consequence because the flux rate would be small, and the chemistry of the condensate would be benign, at a pH of approximately 5.6 (Bechtel SAIC Company, LLC, 2005b).

NRC staff have no more questions on the transparency of excluding dripping from underneath the drip shield. Staff notes, however, that assumptions related to design options may need to be revisited if the design for the potential License Application changes from that used in Bechtel SAIC Company, LLC (2005b). Of specific concern to Comment 59, and thus FEP 2.1.08.14.0A, is the assumption of well-ventilated drip shield design. Results in Bechtel SAIC Company, LLC (2005b) for non-ventilated drip shield designs may not support the exclusion of FEP 2.1.08.14.0A.

In summary, Williams (2006) stated that repository-scale cold-trap processes now will be included in the performance assessment for the potential License Application. Furthermore, a transparent basis was provided in Bechtel SAIC Company, LLC (2004c, 2005b) for excluding dripping of condensate from the underside of the drip shield. NRC notes, however, that assumptions and analyses may need to be revisited if the design used in the potential License Application differs from that assumed in Bechtel SAIC Company, LLC (2005b). The additional information provided in Williams (2006) was responsive and informative. NRC has no further questions at this time.

4.3 Association with Agreements TEF 2.05 and GEN 1.01, Comments 5 and 16

Williams (2006) noted that KTI Agreement TSPAI 2.02, Comment 59, was linked to KTI Agreements TEF 2.05 and GEN 1.01, Comments 5 and 16. Because repository-scale cold-trap processes were changed from excluded to included, review of the newly released documents provided with the DOE letter falls under the model abstraction agreements TEF 2.05 and GEN 1.01, Comments 5 and 16. NRC's comments for these agreements were contained in a letter dated April 15, 2005 (Kokajko, 2005b). Those comments are summarized and updated here.

Whereas DOE had provided enough information for NRC to close the agreements, Kokajko (2005b) provided comments in three technical areas for DOE to consider: (i) clarify the use of inconsistent design options to support assumptions, model conceptualizations, and conclusions; (ii) determine availability of data to support numerical model estimates of condensation along drifts over time; and (iii) clarify basis of unsupported dispersion coefficients for in-drift cells in the porous media models. Based on the enclosures in Williams (2006), updated comments on these three areas are provided below.

For the first area, staff notes that two different design options are used to develop upper and lower-bound estimates of the effect of convection and condensation on in-drift temperature and relative humidity. A design option with no bulkheads at the end of drifts is used to develop an upper-bound. This development accordingly uses an upper-bound estimate of the dispersion coefficient. For the lower-bound estimate, bulkheads are placed near waste packages at the ends of drifts. This development accordingly uses lower-bound estimates of dispersion coefficients. The use of inconsistent design options affects the upper-bound estimate most, and appears inconsistent with the notion of an upper-bound estimate. A design with no bulkheads promotes heat and mass transfer away from the emplacement area, thus reducing waste package temperatures and moving moisture away from the emplacement area. For the second technical area, a peer review of the condensation model approach is used in lieu of model validation (Appendix G to Bechtel SAIC Company, LLC, 2005b). Measurement or observational support, or alternative model results are generally used for model validation. For the third technical area, dispersion values used with the Multiscale Thermohydrological Model (Bechtel SAIC Company, LLC, 2005a) are now linked to results from the computational fluid dynamics models (Bechtel SAIC Company, LLC, 2005b). The NRC staff have no more questions on the basis of dispersion values at this time. Because Williams (2006) indicates that DOE documents (Bechtel SAIC Company, LLC, 2005a, 2005b) continue to be revised, NRC realizes these issues may be clarified by the time the documents are finalized for the potential License Application. Additionally, other questions may arise at the time a potential License Application is reviewed.

In summary, Agreements TEF 2.05 and GEN 1.0, Comments 5 and 16, were previously closed because DOE had provided sufficient information for the NRC staff to evaluate relevant DOE models and assumptions (Kokajko, 2005b). The NRC staff, however, identified three technical comments for DOE to consider. Of these three technical comments, Williams (2006) and enclosures addressed the comment about the basis for dispersion values used in porous media models. The other two technical comments from Kokajko (2005b) have not been addressed. The first remaining comment is that the reliance of upper-bound analyses on assumptions for design options are inconsistent with designs used elsewhere, and inconsistent with the concept of an upper-bound estimate. The second remaining comment is that there is lack of observational data or alternative model analyses to support numerical models of condensation along drifts. These two comments, and any other comments that arise, will be considered at the time the potential License Application is reviewed.

5.0 SUMMARY

The NRC staff evaluated the DOE response to the AIN for KTI Agreement TSPAI 2.02, Comment 59, concerning transparency of the basis for excluding repository-scale convection and condensation processes, and for excluding dripping from underneath the drip shield from performance assessments. DOE has changed the repository-scale convection and condensation FEP from excluded, to included, in the performance assessment (Williams, 2006). DOE also provided details supporting the exclusion of dripping from underneath the drip shield (Bechtel SAIC Company, LLC, 2004c, 2005b). The NRC staff concludes that the information DOE provided in the Williams (2006) letter and accompanying documents satisfies the AIN. Notwithstanding new information, and awaiting design selection that could raise new questions or comments, the information provided satisfies the intent of the Agreement TSPAI 2.02, Comment 59.

For agreements TEF 2.05 and GEN 1.01, Comments 5 and 16, three technical comments from Kokajko (2005b) are summarized and updated in this enclosure. Of the three, the comment on in-drift dispersion values used in the porous media model was addressed by information contained in the enclosures of Williams (2006). The other two comments were not addressed.

NRC will make its final determination on any issue relevant to licensing during review of any potential License Application, at which time other questions may arise.

6.0 STATUS OF THE AGREEMENTS

Based on the preceding review, the information provided by DOE (Williams, 2006) satisfies the intent of KTI Agreement TPSAI 2.02, Comment 59. Therefore, NRC considers this agreement closed.

Agreements TEF 2.05 and GEN 1.01, Comments 5 and 16, are topically related to TSPAI 2.02, Comment 59, and were previously considered closed by NRC (Kokajko, 2005b), because enough information was available to evaluate the relevant DOE models and assumptions. Technical comments for DOE to consider were provided in Kokajko (2005b), and are updated in Sections 4.3 and 5.0 of this enclosure. NRC believes that Agreements TEF 2.05 and GEN 1.01, Comments 5 and 16, should remain closed.

7.0 REFERENCES

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