

REVIEW BY THE U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
OF THE U.S. DEPARTMENT OF ENERGY AGREEMENT RESPONSES RELATED TO THE
POTENTIAL GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, NEVADA:
FOR KEY TECHNICAL ISSUE EVOLUTION OF THE NEAR-FIELD ENVIRONMENT
AGREEMENTS (ENFE.1.03, 1.04, 1.05, 1.07, and 4.02)

1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) issue resolution goal during this interim precicensing period is to ensure the U.S. Department of Energy (DOE) has assembled enough information about a given issue for NRC to accept a potential license application for review. Resolution by NRC staff during precicensing does not prevent anyone from raising any issue for NRC staff consideration during the licensing proceedings. It is equally important to note that resolution of an issue by NRC staff during the precicensing period does not prejudice the NRC evaluation of the issue during the licensing review. Issues are resolved by NRC staff during precicensing when the staff has no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments about a previously resolved issue.

Several documents were submitted by DOE to satisfy the information needs of Key Technical Issue (KTI) Agreements Evolution of Near-Field Environment (ENFE).1.03, 1.04, 1.05, 1.07, and 4.02. By letter dated July 30, 2004, DOE submitted Appendix F of Technical Basis Document No. 3 (Bechtel SAIC Company, LLC, 2004a). Appendix F [Revisions to Report on Drift-Scale Coupled Processes (Drift Scale Test (DST) and Thermal-Hydrological-Chemical (THC) Seepage) (Response to ENFE.1.03, AIN-1)] and the previously submitted report, Drift-Scale Coupled Processes (DST and THC Seepage) Models, Revision 02 (Bechtel SAIC Company, LLC, 2003a), provide information to satisfy the information needs of KTI Agreement ENFE.1.03. By letter dated August 31, 2004, DOE transmitted Appendix D of Technical Basis Document No. 10 (Bechtel SAIC Company, LLC, 2004b). Appendix D (Effects of Cementitious Material on Unsaturated Zone Flow and Transport) provides information to satisfy the information needs of KTI Agreement ENFE.1.04. By letter dated November 25, 2003, DOE submitted Appendix B [Uncertainty and Variability in the Near-Field Geochemical Environment (Response to ENFE.1.05, TSPA.3.09, and GEN.1.01, Comments 81, 93, 98, 104, and 110)] of Technical Basis Document No. 5 (Bechtel SAIC Company, LLC, 2003b) to satisfy the information needs of KTI Agreement ENFE.1.05. By letter dated May 27, 2004, DOE submitted Bechtel SAIC Company, LLC (2004c) to satisfy the information needs of KTI Agreements ENFE.1.07, and ENFE.4.02.

The information provided in the documents was requested by NRC staff during a technical exchange in January 2001 (Reamer, 2001) and in subsequent letters requesting additional information (Schlueter, 2003, 2002). In its transmittal letters, DOE recommended that agreements ENFE.1.03, 1.04, 1.05, 1.07, and 4.02 be closed because the information or the documents requested in the agreements have been provided.

Enclosure

2.0 WORDINGS OF THE AGREEMENTS

2.1 KTI Agreement ENFE.1.03

“Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02, including (1) information on the quantity of unreacted solute mass that is trapped in dry-out zone in TOUGHREACT simulations, as well as how this would affect precipitation and the resulting change in hydrologic properties and (2) documentation of model validation consistent with DOE’s QA requirements. DOE will provide documentation of model validation, consistent with DOE’s QA requirements, in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL–NBS–HS–000001), Rev. 01, expected to be available to the NRC in March 2001. DOE will provide information on the quantity of unreacted solute mass that is trapped in the dry-out zone in TOUGHREACT simulations in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 02, expected to be available to the NRC in FY 02.”

The request for additional information reads (Schlueter, 2002):

“The NRC reviewed Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL–NBS–HS–000001), Rev. 01, ICN 00, as it pertains to the agreement, and it only partially satisfies the agreement. According to information received at the ENFE Technical Exchange (presentation by Sonnenthal and Apps, January 2001), this revision of the document was to contain the technical basis for neglecting coupled thermal-hydrological-chemical (THC) alterations of the Calico Hills nonwelded (CHn) hydrogeological units. Specifically, NRC was told that MDL–NBS–HS–000001, Rev. 01 contains simulation results demonstrating that ‘resulting porosity, permeability, and mineralogical changes in the CHn are expected to be inconsequential.’ Staff understands that the THC modeling described in MDL–NBS–HS–000001, Rev. 01, does include the CHn hydrogeological units, but simulation results specifically related to alteration of the CHn hydrogeological units are not presented in MDL–NBS–HS–000001, Rev. 01.

In the next revision of the document, provide the information discussed above, as well as the information discussed in the second half of the agreement.”

2.2 KTI Agreement ENFE.1.04

“Provide additional technical bases for DOE’s treatment of the effects of cementitious materials on hydrologic properties. DOE will provide additional information on the effects of cementitious materials in an update to the Unsaturated Zone Flow and Transport PMR (TDR–NBS–HS–000002), available in FY 02. Information provided will include results of evaluation of the magnitude of potential effects on hydrologic properties and radionuclide transport characteristics of the unsaturated zone.”

2.3 KTI Agreement ENFE.1.05

“Address the various sources of uncertainty [e.g., model implementation, conceptual model, and data uncertainty (hydrologic, thermal, and geochemical)] in the THC model. DOE will evaluate the various sources of uncertainty in the THC process model, including details as to how the propagation of various sources of uncertainty are calculated in a systematic uncertainty analysis. DOE will document that uncertainty evaluation in the Drift-Scale Coupled Processes

(DST and THC Seepage) Models AMR (MDL–NBS–HS–000001) Rev. 02 (or in another future document), expected to be available in FY 02.”

2.4 KTI Agreement ENFE.1.07

“Provide physical evidence that supports the model of matrix fracture interaction precipitation effects (e.g., coring). DOE will provide the following evidence that supports the model of matrix/fracture interaction precipitation effects: (1) Existing data from the Single Heater Test (SHT) of post-test overcoring Mineralogy-Petrology (Min-Pet) analysis [SHT final report (MOL.20000103.0634) and DTN LASL831151.AQ98.001] is expected to be provided to the NRC in March 2001. (2) Results of ongoing side-wall sampling Min-Pet analyses of DST samples are expected to be provided to the NRC in FY 02. (3) DOE expects to provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models (MDL–NBS–HS–000001) Rev. 01 to the NRC as evidence of matrix-fracture interaction in March 2001.”

The request for additional information reads (Schlueter, 2003):

“A comparison between the THC simulation predictions and observational data is needed to allow staff to evaluate model support and model justification considerations.”

2.5 KTI Agreement ENFE.4.02

“Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02. DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL–NBS–HS–000001), Rev. 01, to the NRC in March 2001. DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 02, to the NRC in FY 02.”

3.0 INFORMATION PROVIDED IN DOE’S AGREEMENT RESPONSE

3.1 KTI Agreement ENFE.1.03

In Appendix F of Technical Basis Document No. 3 (Bechtel SAIC Company, LLC, 2004a), DOE identified three items addressed in the agreement and the subsequent request for additional information: (i) treatment of unreacted solute mass in dry regions in TOUGHREACT simulations and its impact on thermal-hydrological-chemically induced property changes, (ii) support for the thermal-hydrological-chemical model, and (iii) simulation results related to thermal-hydrological-chemically induced alterations in the Calico Hills nonwelded unit.

3.1.1 Treatment of Dry Regions in TOUGHREACT Simulations

Numerical simulations using the TOUGHREACT software are used by DOE to assess the potential for thermal-hydrologic-chemically induced changes in the hydrological properties of the rocks near the repository emplacement tunnels. The TOUGHREACT simulations include multiphase flow and multicomponent reactive transport in a dual continuum formulation. With significant heating of the rock because of the emplaced waste, some gridblocks may become dry because of boiling and evaporation. In the TOUGHREACT simulations, liquid water may flow into a dry gridblock from an upstream gridblock that contains liquid water. Revision 1 of

Bechtel SAIC Company, LLC (2002) used Versions 2.2 and 2.3 of TOUGHREACT. In those versions of the software, solute mass carried into a dry gridblock by water flowing from an upstream block is held in an unreacted state until water returns to the dry gridblock. During the technical exchange in January 2001, NRC staff pointed out this algorithm artificially suppresses mineral formation. The agreement requests DOE to provide information about the consequences of this numerical suppression of mineral precipitation.

In response to this agreement, DOE provided Revision 2 of Bechtel SAIC Company, LLC, (2003a) and Appendix F of Technical Basis Document No. 3 (Bechtel SAIC Company, LLC, 2004a). The modeling described in those documents used Versions 2.4 and 3.0 of the TOUGHREACT software. The improved versions of the TOUGHREACT software have a new algorithm to better handle mineral precipitation near dry gridblocks. Specifically, solute mass entering a dry gridblock is precipitated, stoichiometrically, and with a predetermined order. Silica forms first, followed by calcite, gypsum, hematite, fluorite, and six highly soluble salt minerals. The algorithm is designed to precipitate as much of the dissolved mass as possible, thus avoiding the numerical artifacts of previous versions.

Modeling results using Versions 2.4 and 3.0 of TOUGHREACT show greater mineral precipitation near the emplacement tunnels compared with earlier versions. Fracture permeability is reduced by one order of magnitude or more in a thin region because of precipitation of amorphous silica. The region of mineral precipitation is located approximately 5 m [16.4 ft] from the drift wall. Permeability reduction in that location is not expected to have adverse consequences on drift seepage.

3.1.2 TOUGHREACT Validation

The agreement requests additional information about validation activities related to the thermal-hydrological-chemical modeling. In Revision 2 of Bechtel SAIC Company, LLC (2003a) and in Appendix F of Technical Basis Document No. 3 (Bechtel SAIC Company, LLC, 2004a), DOE described three model validation studies. Specifically, thermal-hydrological-chemical simulations were compared with results of the Drift-Scale Test, a laboratory flow-through experiment on dissolution in crushed tuffs and a fracture plugging experiment. Because the ENFE.1.03 agreement addresses thermal-hydrological-chemical effects on seepage and flow, comparisons between predicted and observed mineralogical changes are most relevant. Model validation related to aqueous geochemical changes are addressed in DOE's response to the ENFE.2.17 agreement, presented in Appendix K of Technical Basis Document No. 5 (Bechtel SAIC Company, LLC, 2003b).

Observations from the Drift-Scale Test provide DOE with the primary means of validating the thermal-hydrological-chemical model. DOE collected and analyzed gas, water, and mineral samples from the test and compared these to detailed numerical simulations. The simulations predicted small amounts of mineral precipitation in fractures near the heater drift. Amorphous silica was predicted to be the dominant mineral precipitated in the boiling zone. Smaller amounts of calcite and gypsum also were predicted in the simulations. These simulation results agreed in general terms with the observed mineralogical changes. Specifically, newly precipitated amorphous silica, calcite, and gypsum were observed in samples removed from the boiling zone. No other phases have been identified so far (Bechtel SAIC Company, LLC,

2004a). DOE estimated the volume of precipitated silica to be less than 1 percent of the fracture volume, although there is significant uncertainty in that estimate. The locations of the observed mineralogical changes agreed generally with the simulations.

The laboratory flow-through experiment was designed to test the capability of the simulation model to predict mineral dissolution in crushed tuff. The experiment was performed at elevated temperature and isothermal conditions. Inlet water in the flow-through experiment was obtained by equilibrating deionized water with a CO₂/N₂ gas mixture, resulting in a pH of 4.58. Concentrations of major constituents in the effluent were monitored. The steady-state concentrations of silica and sodium agreed closely with the modeling results. Measured concentrations of calcium were a factor of two smaller than the simulation results. Alkalinity (reported as CaCO₃) was within a factor of four of the modeling results.

The fracture plugging experiment was performed on a welded tuff block containing a vertically oriented fracture. A temperature gradient was imposed so temperature at the bottom of the fracture was above boiling and temperature at the top of the fracture was below boiling. Water leaving the crushed tuff flow-through experiment was introduced into the top of the fracture and allowed to flow into the boiling zone. The fracture became plugged with minerals after approximately 5 days. DOE compared the results qualitatively with simulations. The simulation shows significant plugging of the fracture because of precipitation of amorphous silica, in agreement with the experiments. The location, extent, and mineralogy of the fracture plugging minerals agree with the experiment.

3.1.3 Alteration of the Calico Hills Nonwelded Hydrogeological Unit

In Revision 2 of Bechtel SAIC Company, LLC (2003a), the model grid was extended vertically to the water table to better represent thermal conditions in the Calico Hills nonwelded hydrogeological unit. Results are summarized in Appendix F of Technical Basis Document No. 3 (Bechtel SAIC Company, LLC, 2004a).

DOE's simulations show that temperatures at the top of the Calico Hills nonwelded unit may increase to approximately 75 EC [167 EF] at 2,000 years. Temperatures greater than approximately 50 EC [122 EF] are thought to be sufficient to cause mineralogical changes in the vitric and zeolitic tuffs. Simulation results show that nearly 20 percent of the volcanic glass in the Topopah Spring welded basal vitrophyre, which is located just above the Calico Hills nonwelded unit, may be altered at 7,000 years. Within the Calico Hills nonwelded unit, clinoptilolite and glass alter to feldspars and stellerite. DOE does not provide information about the magnitude of the mineralogical changes in the Calico Hills nonwelded but notes the resulting change in matrix porosity is approximately 1 percent or less. Changes in fracture permeability are much smaller. DOE's model relates permeability changes to porosity only, independent of mineralogy. With that assumption, a 1-percent change in porosity has minor and inconsequential changes in permeability and flow paths in the unsaturated zone.

3.2 KTI Agreement ENFE.1.04

Appendix D of Technical Basis Document No. 10 (Bechtel SAIC Company, LLC, 2004b) provides information related to agreement ENFE.1.04. This agreement requests DOE to provide the technical bases for its treatment of the effects of cementitious materials on hydrologic properties and radionuclide transport characteristics of the unsaturated zone.

These materials potentially could affect repository performance by modifying the hydrological properties of the surrounding rock or enhancing radionuclide transport to the accessible environment, either through aqueous complexation of radionuclides or through transport by pseudocolloids.

As mentioned in Appendix D and presented in Bechtel SAIC Company, LLC (2004d), cementitious materials (i.e., cement grout in ground support) are no longer part of the emplacement design for the engineered barrier system. Cementitious material (shotcrete) still is planned as part of the ground support for the turnout intersections of the main access drifts and for intersections of the exhaust drifts with the emplacement drifts. Current plans by DOE, however, call for the removal of all cementitious material not required for ground support (Bechtel SAIC Company, LLC, 2004e). The estimated total mass of cementitious material to remain in the potential repository, based on current design concepts (Bechtel SAIC Company, LLC, 2004f), is 1,900 and 59,400 metric tons [2,100 and 65,600 tons] of cement grout and shotcrete (Bechtel SAIC Company, LLC, Appendix D, Table D–1 respectively). DOE's evaluation of the potential effects of cementitious materials considered only the impact of materials planned to remain in the potential repository.

As discussed in Appendix D, DOE considered several processes in evaluating the potential impact of cementitious materials on repository performance: (i) dehydration; (ii) hydrothermal recrystallization; (iii) carbonation; (iv) formation and migration of hyperalkaline plumes; (v) calcite precipitation and permeability modification in unsaturated zone host rocks; and (vi) colloid generation and transport. DOE determined the cementitious materials that would remain in the potential repository would not have a significant effect on the hydrological properties and radionuclide transport characteristics of the unsaturated zone, and these materials would not significantly affect repository performance. DOE's technical bases for these conclusions are provided in Appendix D of Technical Basis Document No. 10 (Bechtel SAIC Company, LLC, 2004b).

3.3 KTI Agreement ENFE.1.05

Appendix B of Technical Basis Document No. 5 (Bechtel SAIC Company, LLC, 2003b) and the supporting report (Bechtel SAIC Company, LLC, 2003a) provide information related to the subject agreement. Results summarized in Appendix B are relevant to KTI Agreements ENFE.1.05, ENFE.2.05, TSPAI.3.09, and GEN.1.01. The following discussion addresses ENFE.1.05 only.

Numerical simulations using the TOUGHREACT software are used by DOE to assess the potential for thermal-hydrological-chemically induced changes in the hydrological properties of rocks near the repository emplacement tunnels. The complex simulations include multiphase flow and multicomponent reactive transport in a dual continuum formulation, and they are subject to significant data and conceptual uncertainties. The ENFE.1.05 agreement was initiated to ensure these uncertainties had been captured adequately in the modeling and model abstractions.

DOE used sensitivity analyses to develop qualitative understanding and quantitative results regarding the effects of uncertainties. The analyses addressed sensitivity to initial chemical conditions, kinetic rates, equilibrium constants, assumed vapor pressure model, numbers and types of minerals tracked in the simulations, and water infiltration rates. Simulations for two

different repository locations were used to address the effect of spatial variability. Geostatistical simulations of fracture permeability and the capillary-pressure-strength parameter were used to address the effect of heterogeneity in hydrological properties.

Of the sensitivities addressed, the largest effect on hydrological properties was heterogeneity in the fracture properties. When heterogeneity was included, permeability was reduced by a factor of three because of mineral precipitation, but only in highly localized areas. DOE did not address the effect of such changes on seepage. Instead, DOE pointed out the thermal-hydrological-chemically induced changes in permeability are small compared with the initial spatial variability in permeability, and this larger spatial variability is already included in the numerical simulations (Bechtel SAIC Company, LLC, 2003c) used to develop drift seepage abstractions.

3.4 KTI Agreement ENFE.1.07

By letter dated September 26, 2002, DOE submitted Response to ENFE.1.07: Results of Side-Wall Sampling Min-Pet Analyses of Drift-Scale Test Samples. The letter report summarizes mineralogic and petrologic analyses of a pretest drill core and of side-wall cores removed during the test period. The analysis of the pretest core provides information about initial mineral abundances that can help constrain initial conditions for thermal-hydrological-chemical models. The side-wall sampling results revealed new deposits of amorphous silica, gypsum, and calcite on borehole surfaces and, to a lesser extent, on natural fractures within the core samples. Only one sample showed evidence of dissolution during the test period. Because of the sparse nature of the side-wall sampling and the small size of the recovered samples, the side-wall sampling results are largely semiquantitative, i.e., the results are limited to descriptions and some quantitative data about mineral deposit thicknesses. The letter report provided no comparisons between the thermal-hydrological-chemical simulations and the observational data. Thus, NRC requested DOE to provide additional information to support closure of the subject agreement (Schlueter, 2003).

The additional information requested by NRC staff was provided by DOE in Bechtel SAIC Company, LLC (2004c). This report provides comparisons between TOUGHREACT simulations and the results of side-wall cores removed during the test periods. The TOUGHREACT simulations predict small amounts of amorphous silica precipitation on fracture surfaces. Extremely minor amounts of calcite and gypsum also are predicted to precipitate in and near the location of the boiling zone. The resulting effects on fracture and matrix porosity are predicted to be negligible. These results from the TOUGHREACT simulations generally are consistent with observations from the side-wall sampling. In particular, TOUGHREACT simulations correctly predicted the precipitated mineral phases and the general location of newly precipitated minerals. Although the side-wall sampling is too sparse to provide quantitative constraints about the volume of mineral deposits, it is clear that the deposits are minor and unlikely to affect significantly porosity and hydrological conditions.

3.5 KTI Agreement ENFE.4.02

The KTI agreement states DOE was to provide Revisions 1 and 2 of Drift-Scale Coupled Processes (DST and THC Seepage) Models to NRC. DOE submitted Revision 2 of the report with its letter dated May 27, 2004. Revision 1 of the report was submitted in March 2001.

4.0 NRC EVALUATION AND COMMENT

The following sections provide discussions of the relevance of the agreements to repository performance and the results of the NRC review of the agreement responses.

4.1 KTI Agreement ENFE.1.03

The three topics addressed in the agreement ENFE.1.03 response are considered separately in the following subsections.

4.1.1 Treatment of Dry Regions in TOUGHREACT Simulations

Relevance to Repository Performance

Performances of drip shields and waste packages may be affected directly by the quantity and chemistry of water contacting them. Drift seepage, one of the direct controls on the quantity of water contacting engineered barriers and waste forms, potentially is affected by thermal-hydrological-chemically induced changes, such as mineral dissolution and precipitation, in rocks near the repository emplacement drifts. DOE's basis for neglecting thermal-hydrological-chemically induced hydrological changes depends in large part on results from TOUGHREACT simulations, and it is important to understand the consequences of model artifacts like those introduced by the TOUGHREACT Version 2.3 treatment of dry regions.

Result of the NRC Review

Part of agreement ENFE.1.03 focused on adequacy of the numerical algorithm for predicting mineral precipitation at the position of the boiling front in TOUGHREACT Versions 2.2 and 2.3. In response to this agreement item, DOE developed an improved algorithm for mineral precipitation and incorporated this algorithm in TOUGHREACT Versions 2.4 and 3.0. The new algorithm described in Revision 2 of Bechtel SAIC Company, LLC (2003a) avoids the artificial suppression of mineral precipitation and results in much greater mineral precipitation compared with TOUGHREACT Versions 2.2 and 2.3. NRC agrees with the new treatment of mineral precipitation in the simulation and concludes DOE has provided the requested information related to the TOUGHREACT treatment of mineral precipitation. NRC also agrees that mineral precipitation at locations 5 m [16.4 ft] from the drift wall is not likely to have an adverse effect on drift seepage. Therefore, NRC staff considers that topic one addressed by ENFE.1.03 agreement complete. Future NRC staff reviews will focus on potential thermal conditions that might cause this mineralized zone to form close to the drift walls because drift seepage is sensitive to hydrological conditions at that location.

4.1.2 TOUGHREACT Validation

Relevance to Repository Performance

Performances of drip shields and waste packages may be affected directly by the quantity and chemistry of water contacting them. Drift seepage, one of the direct controls on the quantity of water contacting engineered barriers and waste forms, potentially is affected by thermal-hydrological-chemically induced changes, such as mineral dissolution and precipitation, in rocks near the repository emplacement drifts. DOE's basis for neglecting

thermal-hydrological-chemically induced hydrological changes depends in large part on results from TOUGHREACT simulations, and it is important that sufficient support be provided for the complex TOUGHREACT model.

Result of the NRC Review

The TOUGHREACT simulations agree in general terms with the locations and magnitudes of precipitated minerals observed from the three validation studies. Differences between predicted and observed chemistries are apparent, but these differences do not have significant impact on hydrological properties. DOE provided the requested information related to TOUGHREACT validation as it applies to seepage and flow. Therefore, NRC staff considers that topic two addressed by ENFE.1.03 agreement complete. It should be noted, however, that TOUGHREACT validation related to aqueous chemistry is the subject of another agreement (ENFE.2.17), and the NRC staff review of DOE's responses to that agreement will be provided in a separate document.

4.1.3 Alteration of the Calico Hills Non-welded Hydrogeological Units

Relevance to Repository Performance

Thermal perturbations have the potential to cause alterations in the Calico Hills non-welded hydrogeological unit. If such alterations cause matrix permeability to be reduced sufficiently, flow could be diverted from matrix to fractures, thereby reducing traveltime in the unsaturated zone.

Result of the NRC Review

DOE provided the requested information related to potential changes in the Calico Hills non-welded unit. Specifically, DOE indicates the mineral alteration in the Calico Hills non-welded unit is expected, but the resulting changes in matrix porosity are expected to be small. The effect of uncertainty in the kinetics of mineral alteration is not captured in the thermal-hydrological-chemical model. Also, if matrix permeability depends on porosity alone, as it does in DOE's model, resulting changes in matrix permeability and flow paths are expected to be small. Empirical data (Flint, 1998) from the Calico Hills non-welded vitric and zeolitic units, however, suggest that permeability is not correlated with porosity. Agreement TSPA1.2.02 (Comments J-14 and J-15) is directly linked to the alteration of the Calico Hills non-welded vitric unit, as identified in ENFE.1.03 AIN-1. Therefore, NRC staff considers that topic three addressed by ENFE.1.03 agreement complete. Future NRC staff reviews will focus on the uncertainty of the kinetics of mineral alteration and on the implicit assumption that permeability is dependent on porosity alone and is independent of mineralogy.

4.2 KTI Agreement ENFE.1.04

Relevance to Repository Performance

The use of cementitious materials in the potential repository poses two concerns. One is that leaching of cementitious materials could modify the hydrological properties of surrounding rocks and divert the flow of water entering the drifts. The other is that an alkaline plume resulting from leaching of cementitious materials could enhance radionuclide transport to the accessible

environment, either through aqueous complexation or through the formation of pseudocolloids.

Result of the NRC Review

Agreement ENFE.1.04 focused on the lack of information regarding the effects of cementitious materials on the hydrological properties and radionuclide transport characteristics of the unsaturated zone and on repository performance. DOE plans to remove, prior to repository closure, all cementitious materials not required for ground support and the evaluation presented by DOE in Appendix D of the technical basis document support the conclusion that cementitious materials will not significantly affect repository performance. Based on the NRC staff review of DOE's response to ENFE.1.04, NRC staff finds DOE's response to the agreement to be satisfactory. Therefore, NRC staff considers ENFE.1.04 agreement complete.

4.3 KTI Agreement ENFE.1.05

Relevance to Repository Performance

Performances of drip shields and waste packages may be affected directly by the quantity and chemistry of water contacting them. Drift seepage, one of the direct controls on the quantity of water contacting engineered barriers and waste forms, potentially is affected by thermal-hydrological-chemically induced changes in rocks near the repository emplacement drifts. DOE's basis for neglecting thermal-hydrological-chemically induced hydrological changes depends in large part on results from TOUGHREACT simulations, and it is important to understand the range of uncertainty in these calculations and the consequences of this uncertainty on drift seepage.

Result of the NRC Review

The agreement was developed to ensure that significant uncertainties in DOE's TOUGHREACT simulations were understood and addressed adequately. In response to the agreement item, DOE undertook sensitivity studies to understand the effect of uncertain processes and parameters. These sensitivity studies suggest the amount and location of mineral precipitation are insensitive to the uncertain chemical parameters because the mineral precipitation phenomenon is controlled primarily by thermal processes, which are known with greater confidence. As a result of the thermal conditions, the mineral precipitation zone is located a few meters from the drift wall, and hydrological changes in that location are not expected to have adverse effects on seepage. Moreover, predicted differences in hydrological properties are smaller than the uncertainty range used in the drift seepage abstraction models. NRC staff agrees with the general sensitivity approach and concludes that DOE has provided the requested information. Therefore, NRC staff considers ENFE.105 agreement complete.

Future NRC reviews will focus on two areas: (i) identifying potential thermal conditions that might cause the mineralized zone to form close to the drift walls; and (ii) ascertaining effects of fracture heterogeneity, which were identified by DOE's sensitivity studies as having the largest effect on hydrological properties. Thermal conditions that might cause the mineralized zone to form close to the drift wall potentially are important because drift seepage is sensitive to hydrological conditions at that location. Fracture heterogeneity is of interest because the sensitivity studies that addressed this feature were performed with older versions of TOUGHREACT that numerically suppressed mineral precipitation.

4.4 KTI Agreement ENFE.1.07

Relevance to Repository Performance

Performances of drip shields and waste packages may be affected directly by the quantity and chemistry of water contacting them. Drift seepage, one of the direct controls on the quantity of water contacting engineered barriers and waste forms, potentially is affected by thermal-hydrological-chemically induced changes in rocks near the repository emplacement drifts. DOE's basis for neglecting thermal-hydrological-chemically induced hydrological changes depends in large part on results from TOUGHREACT simulations, and it is important the results of these simulations are compared directly with observations from the drift-scale test.

Result of the NRC Review

The agreement was developed to ensure the results of the TOUGHREACT simulations are compared with direct observations of precipitated minerals on fracture surfaces in the drift-scale test. The results of TOUGHREACT are in general agreement with the observations of types, locations, and amounts of precipitated minerals. NRC staff concludes that DOE has provided the requested information. Therefore, NRC staff considers ENFE.1.07 agreement complete.

4.5 KTI Agreement ENFE.4.02

Relevance to Repository Performance

Performances of drip shields and waste packages may be affected directly by the quantity and chemistry of water contacting them and by coupled thermal-hydrological-chemical processes in the near field. It is important to understand and evaluate the technical bases and approach used by DOE in its models for drift-scale coupled processes.

Result of the NRC Review

The ENFE.4.02 agreement requests DOE to provide Revisions 1 and 2 of Drift-Scale Coupled Processes (DST and THC Seepage) Models. NRC staff has received both documents (revisions) and considers the intent of agreement ENFE.4.02 has been satisfied. Therefore, NRC staff considers ENFE.4.02 agreement complete.

5.0 SUMMARY

NRC reviewed DOE's KTI agreement responses presented in several documents. On the basis of this review, and notwithstanding new information that could raise new questions or comments concerning the noted agreement, NRC staff considers satisfactory DOE's responses to the intent of the agreements ENFE.1.03, 1.04, 1.05, 1.07, and 4.02. Therefore, NRC staff considers ENFE.1.03, 1.04, 1.05, 1.07, and 4.02 agreements complete.

6.0 STATUS OF THE AGREEMENTS

Based on the staff review discussed in previous sections, NRC staff agrees with DOE that the information provided satisfies the intent of the agreements. Therefore, NRC staff considers ENFE.1.03, 1.04, 1.05, 1.07, and 4.02 agreements complete.

7.0 REFERENCES

Bechtel SAIC Company, LLC. "Appendix F: Revisions to Report on Drift-Scale Coupled Processes (DST and THC Seepage) (Response to ENFE.1.03 AIN-1)." Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2004a.

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