U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF U.S. DEPARTMENT OF ENERGY TECHNICAL BASIS DOCUMENT NO. 4: MECHANICAL DEGRADATION AND SEISMIC EFFECTS

Introduction

In Technical Basis Document No. 4: Mechanical Degradation and Seismic Effects, Rev. 1 (Bechtel SAIC Company, LLC, 2004a), the U.S. Department of Energy (DOE) provided information to address 16 U.S. Nuclear Regulatory Commission (NRC)/DOE agreement items (Table 1). The agreements addressed in this document are Repository Design and Thermal-Mechanical Effects (RDTME) 3.02, 3.04–13, 3.15–17, and 3.19, and General (GEN) 1.01 (Comment 3). These agreements address the following NRC staff concerns regarding repository design and thermal-mechanical effects (Tables 1 and 2):

- Geomechanical characterization of the repository rock mass to determine the properties and parameter values needed to evaluate the mechanical behavior of the rock mass relevant to repository design and performance assessment

- Stability of underground openings at the repository during the preclosure period

- Characterization of potential degradation of the emplacement drifts after permanent closure to determine parameter values needed to represent such degradation in performance assessment

The agreements regarding geomechanical characterization request DOE to provide technical basis supporting the parameter values used to represent the mechanical behavior of the repository host rock subjected to combinations of gravity and tectonic loading, thermal loading from radioactive decay of nuclear waste, and ground motion from potential earthquakes. Such technical basis should account for the effects of distributed lithophysae and fractures on mechanical behavior and potential changes in the mechanical properties of the rock that may occur during the period of regulatory concern. The agreements regarding preclosure stability of underground openings request DOE to provide a basis for the openings being sufficiently stable to support repository operations, such as waste emplacement; ventilation (for thermal-load control); monitoring and other performance-confirmation activities; retrieval, if necessary; and closure activities. The agreements regarding degradation of the emplacement drifts after permanent closure request DOE to provide an assessment of rockfall and drift degradation to provide input to the calculation of mechanical loading of the engineered barrier components, seepage into emplacement drifts, and near-field temperature.

Table 1 provides the status of the RDTME agreements and Table 2 provides the wording of each RDTME agreement.

Geomechanical Characterization of the Repository Rock Mass

The information need for geomechanical characterization of the repository rock mass was requested through three agreements: RDTME.3.04 (synthesis of thermal-mechanical parameters including their spatial and temporal variations), RDTME.3.05 (technical basis accounting for the effects of lithophysae on rock-mass properties), and RDTME.3.07 (effects of sustained loading on rock strength). The DOE approach and supporting information are summarized in Bechtel SAIC Company, LLC (2004a, Appendixes A, E, and I). The DOE information for characterizing the lithophysal rocks is based on site geologic mapping, *in-situ* loading tests, laboratory testing of large-diameter cylindrical specimens, and micromechanics-based computer modeling (in which a rock body is represented as an assemblage of interacting particles) to investigate the effects of lithophysae on mechanical behavior. Using this information, DOE developed a relationship between the Young's modulus (E) and the unconfined compressive strength (q_u) of lithophysal rock, divided the lithophysal rock mass into five mechanical-behavior categories based on the q_u-E relationship, and determined the mean and bounding values for E and q_u for each rock-mass category. DOE indicates the five categories correspond approximately to five ranges of lithophysal porosity (Bechtel SAIC Company, LLC, 2004a, p. A-20). A confirmatory analysis of the DOE q_u-E data indicates the upper and lower bounds determined by DOE (except for a truncation of the lower-bound curve suggested by DOE) are approximately coincident with the upper and lower 95-percent confidence limits based on statistical analysis of the data. This observation suggests the DOE-determined upper and lower bounds (without the DOE-suggested truncation of the lower bound) can reasonably represent uncertainties in the q_u-E relationship, if the tested specimens constitute a representative sample of the lithophysal rock units. The uncertainties may result from several factors: sparsity of data; low spatial coverage of sampling; wide variability of fracture intensity and size, shape, and volume fraction of lithophysal cavities; and potential variability of the rock-matrix properties. The representativeness of the data can be verified further through a performance-confirmation program.

Overall, the available information is sufficient to conclude that the geomechanical data necessary to evaluate the mechanical behavior of the repository host rock subjected to combinations of gravity and tectonic, thermal, and seismic loadings, including propagating any uncertainty in the data through the evaluation, will be available at the time of a potential license application.

<u>Preclosure Stability of Underground Openings</u>

The information need for preclosure stability of underground openings was requested through nine agreements. One agreement, RDTME.3.01 (service life of ground support system), has been addressed previously by DOE (Schlueter, 2003). The other eight are addressed in the Technical Basis Document (Bechtel SAIC Company, LLC, 2004a): RDTME.3.02 (critical load combinations), RDTME.3.06 and 3.08 (sensitivity and uncertainty analyses of ground support), RDTME.3.09 (stability of the invert), RDTME.3.10 (dimensionality of analysis models), RDTME.3.11 (long-term degradation of properties), RDTME.3.12 (dynamic response to site-specific ground motion time histories), and RDTME.3.13 (boundary conditions). The DOE approach and supporting information regarding the stability of underground openings are summarized in the technical basis document (Bechtel SAIC Company, LLC, 2004a, Appendixes B, D, F, G, H, and I).

DOE presented an analysis (Bechtel SAIC Company, LLC, 2004a) to make a case that the emplacement drifts would be stable through the preclosure period even without a ground support system. The behavior of the openings without ground support is important because the behavior helps determine what kind of ground support would be needed and what role it would play. Based on its analysis, DOE determined ground support will not be needed for overall stability of the emplacement drifts but will be desirable to retain loose and detached rock that may occur around the periphery of the openings. The DOE analysis (Bechtel SAIC Company, LLC, 2004b,c) considered the first 50 years after waste emplacement, during which time the maximum drift-wall temperature may not exceed approximately 50 °C [122 °F] (Bechtel SAIC Company, LLC, 2004a, p. 5-6) because of heat removal through ventilation.

Staff expect DOE to provide stability analysis for the entire preclosure period (current DOE assumption is 100 years) and include in such analysis a thermal load history consistent with its proposed repository design. Staff analysis (Ofoegbu, et al., 2004) indicates the rock mass around the emplacement drifts will likely experience progressive degradation through exfoliation and raveling because of persistent thermally induced over stress conditions near the periphery of the openings. Such degradation of the openings can be prevented if the thin zone of over stressed rock near the periphery is held in place using an effective ground support system. The ground support system proposed by DOE (Harrington, 2003) potentially can be designed, installed, and maintained to provide the needed support of the openings during the preclosure period. Furthermore, DOE is expected to set up a monitoring and maintenance program to ensure effective performance of its ground support design (Bechtel SAIC Company, LLC, 2004d), which would be consistent with the staff expectation provided in the staff review of the DOE information for completing DOE/NRC agreement RDTME.3.01 (Schlueter, 2003).

Overall, the available information is sufficient to conclude that appropriate information will be available at the time of a potential license application to permit staff assessment of the stability of underground openings at the repository during the preclosure period.

Characterization of Potential Long-Term Degradation of the Emplacement Drifts

The information need regarding characterization of drift degradation after permanent closure was requested through agreements RDTME.3.15 (technical basis for rock bridges between fractures), RDTME.3.16 (representation of fracture planes in stochastic modeling), RDTME.3.17 (effective maximum rock-block size), and RDTME.3.19 (drift-degradation analysis and drift degradation representation in performance assessment). The characterization of potential drift degradation during the postclosure period is important for several reasons. First, sustained mechanical loading from accumulated rockfall rubble may cause damage to the drip shield and, possibly, the waste package if mechanical interactions with the drip shield were to occur. Second, if a sufficient amount of rubble accumulates in the openings early enough to affect heat flow, the insulating effect may cause an increase in temperature of the engineered barrier components. Such an increase in temperature may cause the load-bearing capacity of the drip shield to decrease and potentially may affect waste package corrosion. Third, the presence of rockfall rubble in the openings may affect the potential for seepage water contacting the waste packages.

The DOE approach and supporting information regarding drift degradation are summarized in the technical basis document (Bechtel SAIC Company, LLC, 2004a, Appendixes C and I). DOE performed drift-degradation analysis using two types of models based on the discontinuum approach. This approach to modeling the mechanical behavior of a rock mass consists of representing the rock as a system of interacting blocks. DOE developed one set of discontinuum models in which the blocks are formed through a representation of the site fracture distribution obtained by taking volumetric samples from a stochastically generated three-dimensional fracture network. The models in this set are three-dimensional and were used to determine the characteristics of discrete rock blocks that may strike the drip shield during a seismic event. Such analysis is applicable only to nonlithophysal rock areas because the DOE analysis indicates the lithophysal rocks are not likely to form blocks individually large enough to damage the drip shield. DOE also developed a second set of models in which the rock mass is represented as an assemblage of randomly oriented polygonal blocks. The geometry, strength, and stiffness of the blocks and block interfaces are not determined directly from any characteristics of the rock mass. The block and interface properties, instead, are assigned values such that the overall strength and stiffness of the assemblage match the rock-mass strength and stiffness. The models in this set are two-dimensional and were used to determine the occurrence and extent of drift degradation in lithophysal and nonlithophysal rocks.

DOE concluded, based on the three-dimensional discontinuum models, that drifts in nonlithophysal rock would remain intact except if subjected to low-probability ground motion (corresponding to a hazard level of 10^{-6} or lower probability). Because the fracture representation used in the model has a controlling effect on the calculated results, staff expect any DOE license application to include supporting information to demonstrate the site fracture networks used for drift-degradation analysis adequately represent the geology at Yucca Mountain. For example, staff expect DOE to provide justification for the representation of the low-angle fractures considering the DOE fracture data collected at the site potentially are biased against such fractures because the tunnels used for sampling are nearly parallel to the fractures. Also, staff expect DOE’s license application will include supporting data and justification for the fracture-termination model incorporated in the three-dimensional model. The results of the three-dimensional discontinuum models would be applicable only to a small fraction of the engineered barrier if DOE confirms its current estimate that a maximum of approximately 15 percent of the emplacement drifts will likely reside in nonlithophysal rock. Furthermore, DOE indicates the controlling loading for drip-shield design arises from the accumulated rock rubble calculated based on lithophysal rock modeling; the same drip-shield design would be used everywhere irrespective of rock type. Information regarding lithophysal rocks, therefore, will likely be more important to repository performance than nonlithophysal rocks because the lithophysal rocks are expected to constitute approximately 85 percent of the emplacement drifts, and the drip-shield design loading for the entire repository will likely be determined based on results from lithophysal rock modeling.

DOE made the following conclusions regarding degradation of emplacement drifts in lithophysal rocks based on analyses performed using the second set of models.

- Only a small fraction of the emplacement drifts (i.e., those located in the lowest quality areas of the lithophysal rocks) will experience any significant degradation from the combined effects of thermal loading and potential time-dependent weakening of the rock. DOE estimates that less than 10 percent of the total drift length will belong to this category.

- Seismic ground motion from a potential earthquake with an annual frequency of 10^{-5} or less per year would cause widespread drift degradation. The extent of such seismically induced degradation would vary depending on the peak ground velocity of the seismic ground motion and the lithophysal rock quality.

DOE has provided analysis of potential long-term degradation of drifts in lithophysal rocks using models that appear to simulate important degradation processes such as rock breakage, interactions among broken rock fragments, and gravity-controlled rockfall. Staff analysis, using an alternative conceptual model consistent with available data and current scientific understanding, indicates drift degradation owing to repository thermal loading could be more widespread than estimated by DOE. Ofoegbu, et al. (2004) indicate thermal loading will result in persistent over stress conditions near the periphery of emplacement drifts for at least 1,000 years after waste emplacement. The over stress conditions would develop in all the lithophysal rock-quality categories defined by DOE. Such over stress conditions could cause drift degradation through progressive exfoliation and raveling after the ground support system looses its effectiveness. The potential for such drift degradation could increase as a result of any time-dependent weakening of the rock or occurrence of seismic ground motion. Because of uncertainties in long-term predictions of underground excavations subjected to a combination of mechanical and thermal stresses, the staff believe it would be prudent to consider alternative conceptual models consistent with available data and current scientific understanding, in making design calculations and assessment of performance that will be presented by DOE in its license application.

Staff reviewed available information to determine how DOE intends to account for the following potential effects of drift degradation: mechanical loading of the drip shield and, conceivably, waste package, seepage into drifts, and near-field temperature.

Regarding mechanical loading of the drip shield, DOE indicates it assumes completely collapsed drifts in selecting the rockfall-rubble loads for drip-shield design (Bechtel SAIC Company, LLC, 2004a, p.5-85). The same drip-shield design would be used everywhere irrespective of rock type or drift-degradation estimate. Staff conclude the DOE approach can potentially result in an effective drip-shield design. Staff expect DOE to provide sufficient information to enable staff assessment of this design, considering the variability of potential rockfall loading, potential accumulations of rockfall rubble on the sides and top of the drip shield, increase in drip-shield temperature owing to the insulating effects of rubble, and decrease in the load-bearing capacity of the drip shield owing to the elevated temperature, creep of drip-shield material subjected to sustained loading from accumulated rubble, and the effects of superimposed seismic ground motion. The staff assessment of the DOE information regarding the structural integrity of the drip shield is discussed in more detail in the NRC review of CLST.2.08.

Regarding the effects of drift degradation on seepage, staff review of the DOE approach (Bechtel SAIC Company, LLC 2003a,b) indicates DOE could underestimate drift seepage by using model inputs based on most of the drifts remaining intact during the regulatory period. The DOE approach consists of calculating drift seepage using two lookup tables, representing different categories: category one representing a drift that is essentially intact and category two representing a completely collapsed drift. The category two lookup tables would be applied to drifts in lithophysal rock if (a) drifts are subjected to low-probability ground motions or (b) the rock has undergone a decrease in strength to 40 percent or smaller of the initial value. Category one lookup tables were applied to all other conditions. This approach implies that DOE uses the intact-drift model for the basecase and a mixture of the intact and collapsed-drift models for the seismic scenario in its performance assessment. The DOE calculations indicate the collapsed-drift model results in increased seepage relative to the intact-drift model. Staff calculations using an alternative conceptual model would suggest more widespread drift degradation than DOE estimated for the base-case conditions. Overall, the DOE approach for including the effects of drift degradation in the drift seepage abstraction appears reasonable.

Staff review of the implementation of the DOE approach will focus on determining if the estimates of drift seepage account for the potential effects of drift degradation and the uncertainties in evaluating such effects.

Regarding the effects of drift degradation on temperature, DOE indicates the potential effects of accumulated rubble on the engineered barrier system temperature need not be evaluated because the DOE drift-degradation analysis indicates there would be no significant rubble accumulation in the drifts for more than approximately 1,000 years after waste emplacement (Bechtel SAIC Company, LLC, 2004a, p. 5-86). DOE indicates any degradation occurring after 1,000 years would not have a significant effect on temperature. Staff reviewed other available information regarding the potential effects of elevated temperature on the load-bearing capacity of drip-shield materials and on the waste package corrosion. The effect of higher temperature on drip-shield mechanical performance appears important because of decrease in the yield strength of Titanium Grades 7 and 24 at higher temperatures. This effect, therefore, will be considered in reviewing the DOE drip-shield analysis. Regarding the potential effects on waste package corrosion, the essential effect of rock rubble on temperature is an increase in the exposure time of waste packages to the critical temperature range in which localized corrosion can occur. Because the time for penetration of the thickness of the outer container by localized corrosion is much shorter than the exposure time of waste packages to the critical temperature range with or without rock rubble, an increase in the exposure time is likely to be unimportant to localized corrosion. Thus, DOE has provided sufficient information regarding the effects of drift degradation on the potential corrosion of the waste packages.

<u>Conclusion</u>

Based on a review of DOE's information, staff concludes, that sufficient information will likely be available at the time of a potential license application to permit staff assessment of the geomechanical characteristics and potential response of the repository host rock. To ensure the underground openings will be sufficiently stable during the preclosure period, DOE will provide design information for the openings, an analysis of the design, and a plan to monitor the behavior of the openings and to provide necessary maintenance. Regarding the DOE drift degradation estimates, calculations performed using an alternate conceptual model indicate drift degradation could be more widespread than estimated by DOE. DOE, however, will provide the design and design-analysis information for a drip shield that would be structurally competent to protect the waste package from potential rockfall loading and divert potential seepage water away from the waste package. The RDTME agreements, therefore, are considered closed as described in Table 1.

Table 1 - Status of RDTME Agreement
Table 2 - Wording of RDTME Agreements

Table 1. Status of RDTME Agreements

Staff Concerns	DOE/NRC Agreement	DOE Action	Status of Agreement
Seismic ground motion parameters for repository design and performance assessment	RDTME.2.01 Provide Topical Report 3	See NRC review of TBD #14	See NRC review
	RDTME.2.02 Provide substantive content of Topical Report 3		
	RDTME.3.03 Seismic design input AMR		
Geomechanical characterization of repository host rock to support analysis of the mechanical behavior of the repository host rock subjected to combinations of gravity and tectonic loading, thermal loading from radioactive decay of nuclear waste, and ground motion from potential earthquakes	RDTME.3.04 Synthesis of thermal-mechanical parameters, including spatial and temporal variations	Bechtel SAIC Company, LLC (2004a); Appendixes A and E	Closed. DOE will provide sufficient information to enable staff assessment of geomechanical characteristics and response of repository host rock and also how DOE intends to account for such characteristics and response in its repository design and performance assessment
	RDTME.3.05 Technical basis accounting for effects of lithophysae on rock-mass properties		
	RDTME.3.07 Effects of sustained loading on rock strength	Bechtel SAIC Company, LLC (2004a); Appendix I	

Table 1. Status of RDTME Agreements (continued)

Staff Concerns	DOE/NRC Agreement	DOE Action	Status of Agreement
Stability of underground openings through permanent closure to support repository operation; such as waste emplacement, ventilation (for thermal-load control), monitoring and other performance-confirmation activities, retrieval if necessary, and closure activities	RDTME.3.01 Service life of ground support system	See Schlueter (2003)	Closed. DOE will provide sufficient design information for underground openings, analysis of design, and plan to monitor behavior of openings and provide necessary maintenance through permanent closure
	RDTME.3.02 Critical load combinations	Bechtel SAIC Company, LLC (2004a); Appendixes B, D, F, G, H, and I Bechtel SAIC Company, LLC (2004b) Bechtel SAIC Company, LLC (2004c) Bechtel SAIC Company, LLC (2004d)	
	RDTME.3.06 Sensitivity and uncertainty analyses of ground support		
	RDTME.3.08 Sensitivity and uncertainty analyses of ground support considering fracture patterns		
	RDTME.3.09 Stability of the invert		
	RDTME.3.10 Dimensionality of analysis models		
	RDTME.3.11 Long-term degradation of properties		
	RDTME.3.12 Dynamic response to site-specific ground motion time histories		
	RDTME.3.13 Boundary conditions		
Technical basis for heat removal through ventilation	RDTME.3.14 Justification for numerical models used for ventilation analysis		Closed

Table 1. Status of RDTME Agreements (continued)

Staff Concerns	DOE/NRC Agreement	DOE Action	Status of Agreement
Characterization of potential degradation of emplacement drifts after permanent closure to determine parameter values for representing drift degradation in engineered barrier system design and performance assessment	RDTME.3.15 Technical basis for rock bridges between fractures	Bechtel SAIC Company, LLC (2004a); Appendixes C and I	Closed. An alternative conceptual model indicates drift degradation could be more widespread than estimated by DOE. DOE, however, will provide the design and design-analysis information for a drip shield that would be structurally competent to protect the waste package from potential rockfall loading and divert potential seepage water away from the waste package.
	RDTME.3.16 Representation of fracture planes in stochastic modeling		
	RDTME.3.17 Effective maximum rock-block size		
	RDTME.3.19 Drift-degradation analysis and representation of drift degradation in performance assessment		
	GEN 1.01, Comment 3, Effects of drift collapse		
Stress corrosion cracking of engineered barrier system materials	RDTME.3.18 Technical basis for stress measure used to assess potential for stress corrosion cracking	See NRC review of DOE response to RDTME.3.18	Closed. See NRC review of DOE response to RDTME.3.18.
Potential for water flux diversion from pillar to drift	RDTME.3.20 Thermal-mechanical effects on flow through fractures	Bechtel SAIC Company, LLC (2004e); Appendix G	Closed. DOE will provide sufficient information to enable staff assessment of thermal-mechanical effects on fracture flow.
	RDTME.3.21 Validation of models used to calculate thermal-mechanical effects on fracture flow		
	GEN 1.01, Comments 83 and 97 Thermal-mechanical effects on fracture flow		

REFERENCES

Bechtel SAIC Company, LLC. "Technical Basis Document No. 4: Mechanical Degradation and Seismic Effects." Rev. 1. Las Vegas, Nevada. Bechtel SAIC Company, LLC. 2004a.

Schlueter, J.R. "Prelicensing Evaluation of the Repository Design and Thermal-Mechanical Effects (RDTME) Key Technical Issue (KTI) Agreement 3.01." Letter (November 4) to J.D. Ziegler, DOE. Washington, DC: NRC. 2003.

Bechtel SAIC Company, LLC. "Ground Control for Non-Emplacement Drifts for LA." 800–K.C.–SSD0–00700–000–00A. Las Vegas, Nevada. Bechtel SAIC Company, LLC. 2004c.

Bechtel SAIC Company, LLC. "Ground Support Maintenance Plan." 800–30R–WIS0–00100–000–00A. Las Vegas, Nevada. Bechtel SAIC Company, LLC. 2004d.

Bechtel SAIC Company, LLC. "Technical Basis Document No. 3: Water Seeping into Drifts." Las Vegas, Nevada. Bechtel SAIC Company, LLC. 2004e.

Table 2. Wording of RDTME Agreements	
Subissue #	**NRC/DOE Agreements**
RDTME.201	Provide Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain. Consistent with SDS Subissue 2 Agreement 2, the DOE will provide Seismic Topical Report 3. Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, expected to be available to the NRC in January 2002.
RDTME.2.02	Provide the substantive technical content of Topical Report 3. The DOE will provide the preliminary seismic design input data sets used in Site Recommendation design analyses to the NRC by April 2001. The DOE will provide the draft final seismic design inputs for license application via an Appendix 7 meeting after calculations are complete prior to delivery of Seismic Topical Report 3.
RDTME.3.01	Provide the technical basis for the range of relative humidities, as well as the potential occurrence of localized liquid phase water, and resulting affects on ground support systems. The DOE will provide the technical basis for the range of relative humidity and temperature, and the potential effects of localized liquid phase water on ground support systems, during the forced ventilation preclosure period, in the Longevity of Emplacement Drift Ground Support Materials, AN–EBS–GE–000003 Rev 1, and Rev 1 of the Ventilation Model, AN–EBS–MD–000030, analysis and model reports. These are expected to be available to NRC in September and March 2001, respectively.
RDTME.3.02	Provide the critical combinations of *in-situ*, thermal, and seismic stresses, together with their technical bases, and their impacts on ground support performance. The DOE will examine the critical combinations of *in-situ*, thermal, and seismic stresses, together with their technical bases and their impacts on preclosure ground support performance. These results will be documented in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.
RDTME.3.03	Provide the Seismic Design Inputs AMR and the Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide the Seismic Design Inputs analysis and model report and Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. These documents are expected to be available to NRC in January 2002.

Table 2. Wording of RDTME Agreements (continued)	
Subissue #	**NRC/DOE Agreements**
RDTME.3.04	Provide in the Design Parameter Analysis Report (or some other document) site specific properties of the host rock, as a minimum those included in the NRC handout, together with the spatial and temporal variations and uncertainties in such properties, as an update to the information contained in the March 1997 Yucca Mountain Site Geotechnical Report. The DOE will: (1) evaluate the adequacy of the currently available measured and derived data to support the potential repository licensing case and identify areas where available data may warrant additional field measurements or testing to reduce uncertainty. DOE will provide a design parameters analysis report (or other document) that will include the results of these evaluations, expected to be available to the NRC in fiscal year 2002; and (2) acquire data and/or perform additional analyses as necessary to respond to the needs identified in 1 above. The DOE will provide these results prior to any potential license application.
RDTME.3.05	Provide the Rock Mass Classification Analysis (or some other document) including the technical basis for accounting for the effects of lithophysae. The DOE will provide a rock mass classification analysis (or other document), including the technical basis for accounting for the effects of lithophysae, expected to be available to NRC in fiscal year 2002.
RDTME.3.06	Provide the design sensitivity and uncertainty analyses of the rock support system. The DOE will prepare a scoping analysis to determine the significance of the input parameters for review by NRC staff by August 2002. Once an agreed set of significant parameters has been determined by the DOE and NRC staff, the DOE will prepare an analysis of the sensitivity and uncertainty of the preclosure rock support system to design parameters in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.
RDTME.3.07	The DOE should account for the effect of sustained loading on intact rock strength or provide justification for not accounting for it. The DOE will assess the effects of sustained loading on intact rock strength. The DOE will provide the results of this assessment in a design parameters analysis report (or other document), expected to be available to NRC in fiscal year 2002.
RDTME.3.08	Provide the design sensitivity and uncertainty analyses of the fracture pattern (with respect to Subissue 3, Component 1). The DOE will provide sensitivity and uncertainty analysis of fracture patterns (based on observed orientation, spacing, trace length, etc) on the preclosure ground control system design in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.

Table 2. Wording of RDTME Agreements (continued)	
Subissue #	**NRC/DOE Agreements**
RDTME.3.09	Provide appropriate analysis that shows rock movements in the invert are either controlled or otherwise remain within the range acceptable to provide for retrieval and other necessary operations within the disposal drifts. DOE will provide appropriate analysis that shows rock movements in the floor of the emplacement drift are within the range acceptable for preclosure operations. The analysis results will be provided in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.
RDTME.3.10	Provide technical basis for the assessment that two-dimensional modeling of emplacement drifts is considered to be adequate, considering the fact that neither the *in-situ* stress field nor the principle fracture orientation are parallel or perpendicular to emplacement drift orientation. The DOE will provide the technical bases for the modeling methods used in ground control analysis in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.
RDTME.3.11	Provide continuum and discontinuum analyses of ground support system performance that take into account long-term degradation of rock mass and joint strength properties. The DOE will justify the preclosure ground support system design (including the effects of long-term degradation or rock mass and joint strength properties) in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.
RDTME.3.12	Provide dynamic analyses (discontinuum approach) of ground support system performance using site-specific ground motion history as input. The DOE will provide appropriate analyses to include dynamic analyses (discontinuum approach) of preclosure ground support systems, using site-specific ground motion time histories as input, in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.
RDTME.3.13	Provide technical justification for boundary conditions used for continuum and discontinuum modeling used for underground facility design. The DOE will provide the technical justification for boundary conditions used in modeling for preclosure ground control analyses, in a revision to Ground Control for Emplacement Drifts for SR, AN–EBS–GE–000002 (or other document) supporting any potential license application. This is expected to be available to NRC in fiscal year 2003.

Table 2. Wording of RDTME Agreements (continued)	
Subissue #	**NRC/DOE Agreements**
RDTME.3.14	Provide the results of the ventilation modeling being conducted at the University of Nevada-Reno (Multi-Flux code) and validation testing at the Atlas Facility (validation of the ventilation model based on the ANSYS code), including: (1) the technical bases for the adequacy of discretization used in these models and (2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. The DOE will provide the results of the ventilation test in a update to the Ventilation Model, AN–EBS–MD–000030, analysis and model report including: (1) the technical bases for the adequacy of discretization used in these models and (2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. This is expected to be available to NRC in fiscal year 2002.
RDTME.3.15	Provide field data and analysis of rock bridges between rock joints that are treated as cohesion in DRKBA modeling together with a technical basis for how a reduction in cohesion adequately accounts for thermal effects. The DOE will provide clarification of the approach and technical basis for how reduction in cohesion adequately accounts for thermal effects, including any additional applicable supporting data and analyses. Additionally, the adequacy of the cohesion reduction approach will be verified according to the approach described in Subissue 3, Agreement 22, of the Repository Design and Thermal-Mechanical Effects Technical Exchange. This will be documented in a revision to the Drift Degradation Analysis, AN–EBS–MD–000027, expected to be available to NRC in fiscal year 2003.
RDTME 3.16	Provide a technical basis for the DOE position that the method used to model joint planes as circular discs does not under-represent the smaller trace-length fractures. The DOE will analyze the available small trace-length fracture data from the Exploratory Studies Facility and Enhanced Characterization of the Repository Block, including their effect on block development. This will be documented in a revision to the Drift Degradation Analysis, AN–EBS–MD–000027, expected to be available to NRC in fiscal year 2003.
RDTME.3.17	Provide the technical basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle. The DOE will provide the technical basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle. This will be documented in a revision to Drift Degradation Analysis, AN–EBS–MD–000027 in fiscal year 2003.

Table 2. Wording of RDTME Agreements (continued)	
Subissue #	**NRC/DOE Agreements**
RDTME.3.18	Provide a technical basis for a stress measure that can be used as the equivalent uniaxial stress for assessing the susceptibility of the various engineered barrier system materials to stress corrosion cracking. The proposed stress measure must be consistent and compatible with the methods proposed by the DOE to assess stress corrosion cracking of the containers in WAPDEG and in accordance with the agreements reached at the Container Life and Source Term Technical Exchange. DOE will include a detailed discussion of the stress measure used to determine nucleation of stress corrosion cracks in the calculations performed to evaluate waste package barriers and the drip shield against stress corrosion cracking criterion. DOE will include these descriptions in future revisions of the following: Design Analysis for UCF Waste Packages, AN–UDC–MD–000001, Design Analysis for the Defense High-Level Waste Disposal Container, AN–D.C.–ME–000001, Design Analysis for the Naval SNF Waste Package, AN–UDC–ME–000001, and Design Analysis for the Ex-Container Components, AN–X'S–ME–000001. The stresses reported in these documents will be used in WAPDEG and will be consistent with the agreements and associated schedule made at the Container Life and Source Term Technical Exchange (Subissue 1, Agreement 14, Subissue 6, Agreement 1).

Table 2. Wording of RDTME Agreements (continued)	
Subissue #	**NRC/DOE Agreements**
RDTME.3.19	The acceptability of the process models that determine whether rockfall can be screened out from performance assessment abstractions needs to be substantiated by the DOE by doing the following: (1) provide revised DRKBA analyses using appropriate range of strength properties for rock joints from the Design Analysis Parameters Report, accounting for their long-term degradation; (2) provide an analysis of block sizes based on the full distribution of joint trace length data from the Fracture Geometry Analysis Report for the Stratigraphic Units of the Repository Host Horizon, including small joints trace lengths; (3) verify the results of the revised DRKBA analyses using: (a) appropriate boundary conditions for thermal and seismic loading; (b) critical fracture patterns from the DRKBA Monte Carlo simulations (at least two patterns for each rock unit); (c) thermal and mechanical properties for rock blocks and joints from the Design Analysis Parameters Report; (d) long-term degradation of rock block and joint strength parameters; and (e) site-specific ground motion time histories appropriate for postclosure period; provide a detailed documentation of the analyses results; and (4) in view of the uncertainties related to the rockfall analyses and the importance of the outcome of the analyses to the performance of the repository, evaluate the impacts of rockfall in performance assessment calculations. DOE believes that Drift Degradation Analysis is consistent with current understanding of the Yucca Mountain site and the level of detail of the design to date. As understanding of the site and the design evolve, DOE will: (1) provide revised DRKBA analyses using appropriate range of strength properties for rock joints from a design parameters analysis report (or other document), accounting for their long-term degradation; (2) provide an analysis of block sizes based on the full distribution of joint trace length data from the Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon, AN–EBS–GE–000006, supplemented by available small joint trace length data; (3) verify the results of the revised DRKBA analyses using: (a) appropriate boundary conditions for thermal and seismic loading; (b) critical fracture patterns from the DRKBA Monte Carlo simulations (at least two patterns for each rock unit); (c) thermal and mechanical properties for rock blocks and joints from a design parameters analysis report (or other document); (d) long-term degradation of joint strength parameters; and (e) site-specific ground motion time histories appropriate for postclosure period. This will be documented in a revision to Drift Degradation Analysis, AN–EBS–MD–000027, expected to be available to NRC in fiscal year 2003. Based on the results of the analyses above and subsequent drip shield calculation revisions, DOE will reconsider the screening decision for inclusion or exclusion of the rockfall in performance assessment analysis. Any changes to screening decisions will be documented in analyses prior to any potential license application.

Table 2. Wording of RDTME Agreements (continued)	
Subissue #	**NRC/DOE Agreements**
RDTME.3.20	Provide the sensitivity analyses including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation (from Subissue 3, Component 3, Slide 39). The DOE will provide sensitivity analyses of thermal-mechanical effects on fracture permeability, including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation. This will be provided consistent with site data and integrated with appropriate models in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, AN–NBS–HS–000037, and is expected to be available to NRC in fiscal year 2003.
RDTME.3.21	Provide the results of additional validation analysis of field tests (from Subissue 3, Component 3, Slide 39). The DOE will provide the results of additional validation analysis of field tests related to the thermal-mechanical effects on fracture permeability in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, AN–NBS–HS–000037, and is expected to be available to NRC in fiscal year 2003.

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