2.2.1.3.2 Mechanical Disruption of Engineered Barriers – Set 1
RAIs

REQUEST FOR ADDITIONAL INFORMATION (RAI)
Volume 3—Postclosure Chapter 2.2.1.3.2 (Mechanical Disruption of Engineered Barriers)
1st Set (RAIs 1 through 9)
Drip Shield Capacity Under Static Loading Conditions
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTION 2.2.1.3.2)

Subject: Potential Overestimation of Drip Shield Framework Vertical Load-Carrying Capacity Under Static Loading.

Background: The applicant conducted a series of three-dimensional finite difference analyses using FLAC3D to establish the plastic load limits of the drip shield when subjected to static loading (SAR Section 2.3.4.5.3.3.2). To obtain the drip shield capacity, the applicant increased the vertical load monotonically and monitored the system structural behavior. According to the applicant, the drip shield framework has a substantial design margin against buckling failure under static rubble loading conditions.

The assessment of drip shield vertical load-carrying capacity under static loading is relevant for the dynamic analysis of the drip shield and to establish the loading scenarios used to evaluate waste package performance. These concerns should be integrated with the RAIs related to the following excluding FEPs: 2.1.07.05.0B, "Creep of Metallic Materials in the Drip Shield;" 2.1.03.03.0B, "Localized Corrosion of Drip Shields;" 2.1.06.05.0B, "Mechanical Degradation of the Invert;" and 2.1.07.06.0A, "Floor Buckling." Staff needs this information to determine compliance with regulatory requirements at 10 CFR 63.21(c)(9), (15); 63.113, 63.114.

RAI #1: For the drip shield capacity assessment, provide a technical basis for not increasing the lateral loading as the vertical loading increases. This modeling assumption appears inconsistent with the implemented assumption that drip shield lateral resistance increases as vertical loading increases.

Basis: The model boundary conditions applied to the drip shield sides appear to unduly increase the structural resistance of the drip shield legs. To determine the system capacity, the model assumes the vertical loading of the original loading configuration can increase, but the active lateral rubble loading remains constant (SNL, 2007; Section 6.4.3.2.2.2). This assumption appears inconsistent with other information that indicates an expected increase in lateral load as the height of a rubble pile increases (e.g., BSC, 2004b, Table 5-29). Because of this modeling assumption, there is an increase in the tendency for outward deformation (i.e., "bowing) of the drip shield legs as only the vertical load increases. The applicant counteracts the bowing by applying a reactive lateral resistance whose stiffness is a function of the elastic modulus of the rubble (SAR Section 2.3.4.5.3.3.2).

RAI #2: Demonstrate that the inclusion of model lateral constraints, representing the pallet base over the entire length of the drip shield, does not inappropriately bias the drip shield response in the analysis. Alternatively, provide a separate structural analysis for the drip shield segments that do not contact the pallet base.

Basis: The representative drip shield section of the applicant's model includes a lateral constraint to represent the base of the emplacement pallet (SAR Figure 2.3.4-74). The length of the base pallet, however, is approximately one fifth of the drip shield length.

2.2.1.3.2 Mechanical Disruption of Engineered Barriers – Set 1 RAIs

RAI #3: Provide a technical basis to demonstrate that the effect of loading configuration uncertainty on the drip shield capacity is appropriately represented by the two load cases used in SAR Section 2.3.4.5.3.3.2.

Basis: The applicant assessed drip shield performance under static loading using two loading configurations, which are derived from a set of six configurations for representing static rubble loading for complete drift collapse (SAR Section 2.3.4.5.3.3.2). The applicant used loading case 3, which the applicant stated is the most severe configuration, and the average of the six load cases. According to the applicant, the drip shield performance is relatively insensitive to different loading configurations and two loading cases are sufficient to characterize the system response. Nevertheless, analyses (BSC, 2004a) indicate that the lateral-to-vertical load ratio and asymmetry in the loading configurations may significantly modify the drip shield response.

RAI #4: Provide a technical basis to select the most severe loading configuration with respect to drip shield capacity based solely on the vertical loading, a selection that does not account for the potentially significant effects of lateral loads.

Basis: The applicant indicates that loading case 3 is the most severe among the six computed realizations (SAR Section 2.3.4.5.3.3.2) because case 3 has the highest average vertical load (SAR Section 2.3.4.5.3.2.1). Case 3, however, has one of the smallest lateral-to-vertical load ratios of the six cases (SNL 2007, Table 6.136). As observed in SAR Figure 2.3.4-83, this load configuration is not the most severe case for buckling failure (i.e., cases with plate thinning of 5 and 10 mm).

RAI #5: Demonstrate that additional deformation of drip shield due to the uneven degradation of the invert does not decrease the drip shield capacity. Also, provide the bearing capacity and settlement calculations for the invert.

Basis: SAR Section 2.3.4.5.3.1 indicates that uneven invert degradation would not decrease the drip shield vertical load carrying capacity. To support this conclusion, the applicant developed a model in which the drip shield is rotated as rigid-body prior to applying the static loading (SNL, 2007; Section 6.4.6.1). The drip shield rotation as a rigid body, however, does not account for the effect of additional deformation of drip shield components caused by uneven invert degradation.

RAI #6: Provide an assessment of the effects of gradually accumulating rubble on the drip shield response.

Basis: The drip shield is a free-standing structure that may be subjected to higher lateral-to-vertical load ratios during the early loading stages, leading to inward deformation of the legs that is not accounted in the current analyses.

RAI #7: Provide a technical basis to exclude temperature-dependent effects on titanium material properties used in the drip-shield mechanical analyses for 10,000 years following repository closure. Alternatively, demonstrate that temperatures expected for the drip shield during that time (i.e., greater than 60 °C [140 °F]) will not significantly affect the drip shield mechanical analyses.

Basis: The applicant's drip shield assessment used titanium material properties at 60 °C [140 °F] because, according to SAR Section 2.3.4.5.1.3.1, this temperature maximizes strain and deformation for 99 percent of the 1,000,000 year performance period. This assessment is based on analysis for an intact drift configuration, where the 60 °C [140 °F] temperature threshold would be exceeded during the first 10,000 years at the drift wall (SNL, 2007a; Figure 1-3). Temperatures higher than 60 °C [140 °F] would decrease the mechanical material properties of titanium materials (SAR Section 2.3.4.5.1.3.1; ASME, 2004), potentially decreasing the drip shield capacity. According to the applicant's results, drip shields may be subjected to static and dynamic loads during the first 10,000 years, when temperatures are greater than 60 °C [140 °F] (e.g., SAR Figure 2.1-14). Thus, the potential significance of temperature-dependent effects on titanium material properties must be addressed in the drip-shield mechanical analyses.

RAI #8: Provide a technical basis to support use of the FLAC3D code to represent linear and nonlinear response in the structural analyses. Also provide the input parameters and model assumptions for the alternative structural analysis code that was used in developing support for the FLAC3D methodology (SNL, 2007; Section 7.3.3).

Basis: The applicant's assessment was based on an adaptation of a geotechnical engineering analysis code (FLAC3D) for use in structural analysis. However, conventional input parameters for nonlinear performance evaluation of metal components cannot be directly implemented in FLAC3D (SNL, 2007; Table 6-134). For example, the strain hardening is formulated in terms of the dependence of cohesion on plastic shear strain (SNL, 2007; Section 6.4.2). To support the use of FLAC3D models, the applicant compared deformed shapes and maximum shear stress contours with results obtained using an alternative structural analysis code (SNL, 2007; Section 7.3.3). This comparison, however, presents limited information on the technical basis for input parameters, important model assumptions, and stress and strain distributions. Moreover, the drip shield response for the evaluated cases appears to be mostly in the linear range of the materials, where the nonlinear parameters cannot be tested. Thus, a comprehensive evaluation is needed to show that FLAC3D models provide a reasonable structural response at the expected system performance levels.

RAI #9: Quantify the impact of localized corrosion on the drip shield legs on the drip shield vertical load-carrying capacity.

Basis: The screening argument for FEP 2.1.03.03.0B (SNL, 2008) indicates that localized corrosion could potentially initiate on the side support framework made of Titanium Grade 29, leading to plastic buckling of the sidewall.

References

ASME 2004. "ASME International Boiler and Pressure Vessel Code." New York City, New York: American Society of Mechanical Engineers (ASME) International. 2004.

BSC 2004a. Structural Stability of Drip Shield Under Quasi-Static Pressure. 000-00C-SSE0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040830.0032.

BSC 2004b. Mechanical Assessment of the Drip Shield Subject to Vibratory Ground Motion and Dynamic and Static Rock Loading. CAL-WIS-AC-000002 Rev. 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041028.0004. (MADS)

SNL 2007. “Mechanical Assessment of Degraded Waste Packages and Drip Shields Subject to Vibratory Ground Motion.” MDL-WIS-AC-000001 Rev. 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070917.0006.