REQUEST FOR ADDITIONAL INFORMATION (RAI)
Volume 3—Postclosure Chapter 2.2.1.2.1 (Scenario Analysis)
6th Set (RAIs 1 through 6)
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTION 2.2, TABLE 2.2-5)

The following additional information is needed by the staff to evaluate whether the DOE performance assessment meets the requirements of 10 CFR 63.114(a)(6).

RAI #1:
Demonstrate how the Voronoi block model appropriately represents the characteristics of the Topopah Spring lower lithophysal tuff, such that the potential for drift collapse is not underestimated.

Basis: In the UDEC-Voronoi model, DOE concludes that 30 cm average block diameters with randomly oriented sides are representative of the randomly oriented internal discontinuities within the Topopah Spring lower lithophysal tuff. DOE characterizes the Topopah Spring lower lithophysal tuff as having primarily vertical fractures with spacings on order of several centimeters (BSC 2004, section 7.3.2). Although DOE concludes that the presence of lithophysal voids creates a generally isotropic rock mass (DOE, 2009, RAI-1), DOE did not provide information to show how such voids homogenized the potential effects of a vertical anisotropy in the rock mass.

RAI #2:
Demonstrate how 20-30 cm block sizes in the UDEC Voronoi model appropriately represent potential yielding surfaces that can organize within a rock mass that has an overstressed zone less than 17 cm thick.

Basis: Yielding of overstressed rock is represented in the UDEC-Voronoi model by movement along block surfaces that form a coherent network oriented parallel to the direction of principal compressive stress (e.g., BSC, 2004, section 7.6.5.1). This modeling approach assumes that sufficient block surfaces exist within the overstressed zone to organize a coherent network of surfaces to appropriately represent yielding within the rock mass. DOE concludes that the overstressed zone in heated drifts is less than 17 cm thick (DOE, 2009, RAI-4), which is spanned by only one to two blocks in the model. By comparison with analyses in, for example, BSC (2004, section 7.6.5.1), widths spanning tens of blocks are need to form a coherent network of surfaces to represent yielding within the compressed sample. By analogy, a 1:10 ratio between block size and width of the overstressed zone can be inferred by ASTM Standard D 7012 (2007). DOE sensitivity analyses only considered block sizes to 10 cm diameter (DOE, 2009, RAI-1), which does not adequately represent the fine-scale discretization shown for coherent yielding in other analyses (e.g., BSC, 2004, section 7.6.5.1).

RAI #3:
Provide details of the parametric study that concluded appropriate variations in unconfined compressive strength for the five lithophysal rock categories would not affect significantly the results of the UDEC-Voronoi model. Describe how, for each rock-mass category, appropriate variations in unconfined compressive strength (e.g., SAR Figure 2.3.4-30) were used to calibrate and run the UDEC-Voronoi model.

Basis: Spatial variability in rock properties can potentially affect models for drift collapse. DOE addressed this uncertainty by developing calibrated models for five different rock-strength categories, which are distinguished by different values of rock mass modulus. In conducting its calibration, DOE used the mean value of unconfined compressive strength as the calibration target for each selected value of rock mass modulus. DOE data show a large range of potential values of unconfined compressive strength for a given value of rock mass modulus (SAR, Figure 2.3.4-30). DOE stated (SAR, page 2.3.4-73) that a parametric study was conducted in which the Young's modulus and strength parameters were varied to account for the reasonable bounding ranges of lithophysal and nonlithophysal rock. DOE did not present results of analyses that showed appropriate ranges for rock strength were considered for the five lower lithophysal rock categories.

RAI #4:
Describe how uncertainties in the stress-strain relationships for the Topopah Spring lower lithophysal tuff have been characterized and considered in the UDEC-Voronoi model. Clarify how post-peak strains are represented in the UDEC model for each rock-mass category, such that the effects of brittle deformation have not been underestimated.

Basis: Although the single comparison between the lithophysal tuff and UDEC calculation for stress-strain characteristics does show a calculated response that is more brittle than exhibited by the laboratory experiment (DOE, 2009, RAI-3), this information does not address the range of characteristics represented by the five lithophysal rock-mass categories used in the UDEC analyses. Additionally, strength characteristics for only six samples from the Topopah Spring lower lithophysal tuff are reported in BSC (2007, Table 6-69). Staff cannot determine if these six samples are appropriately representative of the range of strength characteristics needed to support the UDEC analyses (cf. BSC, 2004, Figure 7-16).

RAI #5:
Provide an explanation of how rock blocks at the drift interface maintain cohesion after failure when the modeled stress-strain curve (DOE, 2009, RAI-3, Figure 1-4) indicates a brittle mode of rock failure should occur. Additionally, clarify how blocks in the UDEC-Voronoi model remain in place if the supporting contacts between the blocks have failed.

Basis: DOE concluded the UDEC-Voronoi model shows a more brittle response compared to the stress-strain test on Topopah Spring lower lithophysal tuff (DOE, 2009, RAI-3 and RAI-5). Additionally, the modeled post-peak curves presented in BSC (2004, section 7.6.4) are nearly vertical, and represent a near-brittle mode of deformation (e.g., Jaeger and Cook, 1979). Thus, the near-vertical slope of the post-peak portion of the modeled stress-strain curves suggests that, after failure, the remaining rock strength should be negligible, consistent with a brittle failure mechanism. Additionally, in DOE (2009, RAI-1, Figure 1-3), the UDEC model appears to allow some blocks at the drift wall to remain in place after the supporting contacts between the blocks have failed. This result appears inconsistent with the modeling approach, in which blocks supported by failed contacts should fall from the drift wall.

RAI #6:
Demonstrate how uncertainties in time-dependent failure for Topopah Spring lower lithophysal tuff have been considered in thermo-mechanical analyses for drift collapse, such that the potential for drift collapse has not been underestimated.

Basis: DOE considered uncertainty in the potential effects of time-dependent failure by modeling the mechanical stability of a drift under ambient temperatures using static-fatigue data from granite and welded tuff (BSC, 2004, Appendix S). DOE concludes using a linear fit to the static-fatigue data adequately bounds the uncertainty in time-to-failure, because a straight line underpredicts time-to-failure for rocks with low values of driving stress (DOE, 2009, RAI-2). DOE also concludes that the static-fatigue data for granite overestimate the time to failure, because calculated short failure times appear incompatible with relatively long-term (i.e., 10 years) stability of ESF and ECRB drifts. DOE conducted additional analyses for a heated drift using static-fatigue data for only the welded tuff (BSC, 2004, Appendix S). However, DOE did not provide a comparable thermo-mechanical analysis using static-fatigue data for granite, and DOD did not describe how uncertainties in the available static fatigue data for tuff (e.g., BSC, 2004, Figure 6-155) were considered in analyses for time-dependent failure of lithophysal rocks in heated drifts.

References:

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