REQUEST FOR ADDITIONAL INFORMATION
Volume 3--Postclosure Chapter 2.2.1.3.1—Degradation of Engineered Barriers
3rd Set (RAIs 1 through 5)
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTION 2.3.6.3 and 2.3.6.4)

Topic: Stress Corrosion Cracking of Waste Packages

RAI #1

Provide a technical basis for the assumption that empirical data from testing of Alloy 22 in basic saturated water is sufficient to establish the stress corrosion cracking (SCC) initiation criterion for waste packages that may contact a broader range of potential chemical/material conditions in the repository, including:

- waste package in contact with seepage water brines (e.g. simulated concentrated water and simulated acidic water);
- waste package in contact with deliquescent brines;
- waste package in contact with aqueous chemical solution when there is sulfur accumulation at the metal-passive film interface or at grain boundaries.

Basis: DOE assumes that SCC in the waste package initiates when the residual tensile stress exceeds a threshold value given by a uniform distribution in the range of 90 to 105 percent of the at-temperature yield strength of Alloy 22 (SNL, 2007, Table 6-3). DOE estimates the threshold tensile stress value by conducting constant-load crack-initiation tests on several Alloy 22 samples immersed in 15 percent basic saturated water at 105 °C. Although basic saturated water is one of the representative in-drift chemical solutions that could exist at the repository site, other potential brine solutions, such as simulated concentrated water and simulated acidic water, could also exist in the repository environment (e.g., SAR Table 2.3.6-1). Since DOE has not excluded SCC of Alloy 22 in dust deliquescence brines, the alloy may undergo SCC in dust deliquescence brines which may be considerably more aggressive than basic saturated water. In addition, compositions distinct from basic saturated water also can occur when there is sulfur accumulation at the metal-passive film interface, or at grain boundaries in the presence of an aqueous chemical solution (Jung et al., 2007).

DOE has not provided a technical basis to demonstrate that the use of basic saturated water appropriately represents the range of chemical environments that may occur on a waste package and potentially initiate SCC. The requested information is needed to demonstrate compliance with 10 CFR 63.114(f).

RAI #2

Provide additional technical basis for the assumption that 50 μm is an appropriate depth for incipient stress corrosion cracks in the waste package.

Basis: DOE assumes that stress corrosion cracks could initiate at incipient flaws on a smooth surface when the residual stress is greater than the residual stress threshold (RST). DOE assumes that the depth of cracks that nucleate at incipient flaws is 50 μm at the time of initiation (SAR Section 2.3.6.5.2.2). DOE states that 50 μm is appropriate because it is based on the observation of SCC in nuclear reactor components by Ford and Andresen (1988) and because this depth is greater than the size of initiating cracks stated in NUREG/CR-5864 (Harris et al., 1992), which is 0.001 inch (25.4 μm).

DOE has not provided sufficient information to support the assumption that the crack initiation size in the waste package will be the same as that in nuclear reactor components. The incipient crack depths stated in the cited references are not based on mechanistic understanding of crack initiation, but are based on empirical observations of SCC in nuclear reactor components. Mechanistically, incipient crack size depends upon fundamental characteristics such as material composition, microstructure, type and size of flaws and defects in the material, and chemical environment, among others. Many of these characteristics differ between nuclear reactor components and the waste package. As such, nuclear reactor components may provide limited information regarding the nature of SCC in waste packages unless it is established that the parameters that affect crack size are, in both cases, similar. The requested information is needed to verify compliance with 10 CFR 63.21(c)(15) and 63.114(b).

RAI #3

Provide a technical basis for not considering waste package plate thinning in calculating the number of stress corrosion cracks per patch in the nominal scenario class.

Basis: DOE considers only six through-wall stress corrosion cracks per patch in the TSPA-LA model under the nominal scenario class. DOE states that separation distance between two through-wall cracks should be equal to, or more than, plate thickness. The initial crack separation distance is equal to the thickness of an emplaced waste package plate (25 mm). Based on a patch size of 150 mm x 150 mm, and thickness of 25 mm a maximum of six through-wall cracks could form on a single patch (SNL, 2008, Section 6.3.5.1.2). A plate thinned by general corrosion, however, would require less distance between through-wall cracks than a full-thickness plate. As such, more than six through-wall cracks could be possible on a 150 mm x 150 mm patch that is thinned by the general corrosion.

The crack area model indicates that crack area decreases as the waste package plate thins in the nominal case scenario (SNL, 2007, Section 6.6.2). If only 6 cracks per patch are considered, the through-wall crack area would decrease in proportion to the square of the

thickness of the plate as the plate thins in the nominal scenario class. The through-wall crack area density will approach zero as the thickness of the plate tends to zero. The requested information is needed to verify compliance with 10 CFR 63.114(f).

RAI #4

Provide a technical basis for considering only the residual stress, and not the transient stress during and shortly after impact, in the model abstraction used to calculate the stress corrosion crack size (opening length and opening width) and crack density in the seismically damaged area of the waste package.

Basis: Mechanistically, SCC is typically considered as a three stage process: initiation, propagation, and arrest. DOE, however, uses a non-mechanistic model abstraction for SCC in the seismically-damaged area of the waste package. DOE assumes that through-wall cracks immediately form in areas where the residual stress is greater than the residual stress threshold, which is in the range of 90 to 105% of the Alloy 22 yield stress (SAR Subsection 2.3.4.5.1.2.1). Thus, in the DOE model, stress corrosion crack opening width and opening area depend upon the magnitude of the residual stress (Equations 33 and 34 in SNL, 2007).

Transient stresses during and shortly after impact, however, are higher than the residual stress. The transient stress may affect the size and density of defects in the damaged area, which may in turn affect the size of density of through-wall cracks. DOE has not provided a clear technical basis to support the assumption that such transient stresses do not need to be considered in the model abstraction for SCC in the waste package. The requested information is needed to verify compliance with 10 CFR 63.114(f).

RAI 5

Provide additional technical basis for the assumption that the upper bound for the length of through-wall stress corrosion cracks in the seismically damaged area of the waste package is twice the thickness of the waste package wall.

Basis: For stress corrosion cracks in the seismically damaged area of the waste package, the upper bound for crack length is assumed to be twice the waste package thickness. DOE states that this is the same crack length that is used for radial cracks in the closure weld region in the nominal scenario (SNL, 2007, Section 6.7.3.2). The crack length in the nominal scenario, however, is limited by the attenuation of weld residual stresses normal to the weld-metal interface (SNL, 2007, Section 6.6.1). The size of the stress-field and the distribution of stress magnitude within that field may be much different in the seismically damaged waste package. Conceptual models for crack morphology not considered by DOE (e.g. multiple small cracks coalescing to form a large crack or cracks that span the entire damaged area) might give a crack length that is longer than that assumed in DOE's model abstraction. Cracks with sufficient length may provide a pathway for advective transport of radionuclides through the waste

package wall if the opening width is such that precipitate plugging and crack tortuosity cannot prevent the flow of water through the cracks. The requested information is needed to verify compliance with 10 CFR 63.114(f).

References:

Ford, F.P. and P.L. Andresen. 1988. “Development and Use of a Predictive Model of Crack Propagation in 304/316L, A533B/A508 and Inconel 600/182 Alloys in 288°C Water.” Environmental Degradation of Materials in Nuclear Power Systems—Water Reactors, Proceedings of the Third International Symposium. Traverse City, Michigan. August 30-September 3, 1987. Theus, G.J. and Weeks, J.R., eds. Pages 789-800. Warrendale, Pennsylvania: Metallurgical Society.

Harris, D.O., D.D. Dedhia, and S.C. Lu. 1992. “Theoretical and User's Manual for pc–PRAISE, a Probabilistic Fracture Mechanics Computer Code for Piping Reliability Analysis.” NUREG/CR-5864. Washington, D.C.: U.S. Nuclear Regulatory Commission.

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Jung, H., T. Mintz, D. S. Dunn, O. Pensado, and T. Ahn. 2007. "A Review of the Long-Term Persistence of the Passive Film on Alloy 22 in Potential Yucca Mountain Repository Environments," San Antonio, Texas: CNWRA. ML072880595.