REQUEST FOR ADDITIONAL INFORMATION (RAI)
Volume 3—Postclosure Chapter 2.2.1.2.1 (Scenario Analysis)
4th Set (RAIs 1 through 44)
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTION 2.2.1.2)

Subject: **Exclusion of FEP 2.1.14.19.0A In-Package Criticality Resulting from a Seismic Event (Degraded Configuration), FEP 2.1.14.15.0A In-Package Criticality (Intact Configuration), FEP 2.1.14.16.0A In-Package Criticality (Degraded Configurations), and FEP 2.1.14.18.0A In-Package Criticality (Intact Configuration).**

The RAIs in RAIs 1 through 43 pertain to DOE's technical basis for excluding criticality FEPs based on probability. The information is needed to verify compliance with 10 CFR 63.114 (e), (f).

Either provide the information in your response, or reference specific portions of documents that have been docketed. If you reference docketed documents, provide the title and accession number (MOL number), and the specific page(s) on which the information being sought may be found.

RAI #1: Justify using the number of waste packages rather than the number of neutron absorber plates, tubes or basket components to calculate the probability of criticality for TAD and DOE canisters. This is based on a neutron absorber selection error and the neutron absorbers are individual plates, tubes or basket components that may not be manufactured from the same lot of material (see ANL–EBS–MD–000076 Rev 00).

RAI #2: Justify how additional independent field material inspections will be implemented to ensure reduction of material selection error in absorber plate/tube/basket manufacturing from $1.0*10^{-4}$ down to $1.25 * 10^{-7}$.

RAI #3: Justify application of material selection error in absorber plate/tube/basket manufacturing of $1.0 * 10^{-4}$ using pressure vessel manufacturer's data while neutron absorber plates/tubes/baskets are not required to be manufactured to ASME Boiler and Pressure Vessel Code (Class 1 or Class 2 components) as waste package and TAD canister (see ANL–EBS–MD–000076 Rev 00).

RAI #4: Justify that portable X-ray inspection equipment can reduce the material selection error of neutron absorbers by at least three orders of magnitude since the field X-ray equipment described cannot measure light elements such as boron (see ANL–EBS–MD–000076 Rev 00).

RAI #5: Justify using average corrosion values for borated stainless steel (25-90 ºC) and nickel-gadolinium alloy (30-60 ºC) when the corrosion values range with temperature significantly and these temperatures are lower than repository conditions (see ANL–DS0–NU–000001).

RAI #6: Justify not taking into account localized corrosion of neutron absorber plates and oxide wedging effects of corrosion given that they were experimentally observed. (See ANL–DS0–NU–000001 and ANL-EBS-MD-00037).

RAI #7: Provide information on variability and uncertainty for the non-bounding point-value parameters used in criticality FEPs screening analyses, as required in 10 CFR 63.114(b). Discuss how variability and uncertainty would impact the calculated probability (see ANL–WIS–MD–000027).

RAI #8: Justify that the presented CSNF loading curves for hypothetical canisters would bound the actual canister designs since variations in basket design parameters can have a large impact on the loading curve (see ANL-EBS-NU-000010 REV00).

RAI #9: Justify that the parameters of the hypothetical canisters that have been analyzed in loading curve development are bounding for the actual canisters to be used for loading (see ANL-EBS-NU-000010 REV00).

RAI #10: Provide information on CSNF burnup credit models validation including validation of isotopics depletion and criticality models, as referenced in the SAR. Justify use of the Δk_{ISO} value of negative 0.0249 in the criticality analysis. This bias aggregates positive and negative reactivity effects of all principal isotopes for RCA configurations while the actual net effect might be very different for the actual configurations, and no evaluation of these potential compensatory effects is provided.

RAI #11: Justify using the 0.001 value assigned to the human error probability CHECK_BM_FLAW top event in (ANL–EBS–MD–000076 Rev 00, Section 6.3.2) from NUREG-1278 Table 20-10 (Item 2) that estimates HEP for error of commission in reading digital display instead of Item 4 from the same table: “Checking that involves active participation, such as special measurements”. These measurements are described as checking in nature, involve active measurements, and are described in (ANL-EBS-MD-000076 Rev 00, Section 6.3.2) as follows: “Quick field measurements of material compositions” performed by “the technician assigned to this work”.

The next 8 RAIs pertain to the probability of loading curve violation per WP (i.e., 1.18E-5) as calculated in CAL–WHS–MD–000003.

RAI #12: Justify associating this failure probability solely with a human error when procedure errors, reactor record errors, equipment malfunction, and fuel fabrication/indeterminate errors might also contribute.

RAI #13: Justify why the probability of misloading an assembly is based upon data for dry transfer operations rather than wet transfer operations since the industry data is available for wet transfer (see CAL–WHS–MD–000003 and CAL–WHS–MD–000001).

RAI #14: Justify the assumption made that all shipping records for the fuel assemblies are correct and do not lead to underestimation of misloading events. (Bullet 5.5, page 12 of CAL-WHS-MD-000003).

RAI #15: Provide assessment of the effect of wrong documentation on misload probability. One assumption (Bullet 5.8) is that the documentation for use in the waste package loading process is correct. The study scope of CAL–WHS–MD–000003 does not analyze the process for generating the loading document. However, the effect of wrong documentation should be included in the SAR.

RAI #16: Justify the use of the binomial distribution in calculating single and multiple misloads considering the existence of human performance dependency. The binominal distribution assumes that each assembly selection is independent from the previous selection. It does not consider the possibility that misloads may be related to one another for the same loading team. Revise the analysis so as to address the effect of human performance dependencies on misloads (see CAL-WHS-MD-000003 REV 00A, section 6.2.1).

RAI #17: Justify that the end states of the following event sequences for 21-PWR ABS type waste packages are OK rather than POT-CRIT, as identified on page I-7 of CAL-WHS-MD-000003. The analysis of these event sequences failed to consider the effect of dependency (or dependence in THERP's terminology) on human performance. The analyses of other types of waste packages have the same issue.

- Sequences 12 to 20
- Sequences 23 to 31

RAI #18: Justify the assumption (Bullet 5.4) that "only uncanistered fuel is loaded into the waste packages for this calculation, and all canistered fuel that is shipped to the repository will be loaded into a waste package upon receipt".

RAI #19: Justify not addressing human performance dependency in scenarios 3C and 10C of (CAL-WHS-MD-000003) where the checker belonging to the same loading team fails to verify the correctness of the loaded fuel assembly.

RAI #20: Justify not considering other events in the probability calculations in addition to misloading and manufacturing errors, such as reactor records errors: basket degradation, preferential absorber degradation due to handling damage (developed holes in plates/tubes), fuel/absorber reconfiguration due to the effects of oxide wedging, and accumulation of hydrated corrosion products, separation of absorber plates/tubes that are mechanically assembled. The calculation only considers assembly and neutron absorber misloads as contributors to the potential of criticality (see ANL–DS0–NU–000001).

RAI #21: Justify extending the loading curve beyond the available data for validation (ANL-EBS-NU-000010 REV 00 section 6.3.4.1)

RAI #22: Provide the calculation of the probability of criticality from possible misloads for realistic worst-case loading operations where risk is not diluted by use of entire fuel inventory (i.e., only assemblies from a particular site are available for selection at that site and overall probability of criticality is determined by the site with the most reactive inventory); or justify that the use of uniform random assembly sampling from the total spent fuel inventory is bounding with respect to criticality for realistic loading operations (0.014, as per (ANL-EBS-NU-000010 REV 00 section 6.4).

RAI #23: For each of the 9 types of DOE spent nuclear fuel (DOE SNF), provide:

a. electronic input files for both the intact fuel criticality model and the bounding and representative degraded criticality model. If different models were constructed for the in-package, near-field, and far-field criticality cases, provide the bounding criticality model for each case. The files should be in a form that is suitable to being run.

b. the list of critical benchmark experiments (and, if they are not contained in the International Handbook of Evaluated Criticality Safety Benchmark Experiments, a reference to the source of the experiments) applicable to each criticality model submitted.

c. electronic input files for at least one case from each experimental data set used to validate the criticality models submitted. The files should be in a form that is suitable to being run.

d. justification that the benchmark experiments are applicable to the systems whose models are submitted (e.g., tables comparing the relevant parameters of systems to those of the applicable benchmark experiments, the results of TSUNAMI runs, or other justification).

e. The k_{eff} values for each criticality model submitted, and the bias and uncertainty, and area of applicability, for the benchmarks used to validate them.

RAI #24: For commercial spent nuclear fuel (CSNF), provide:

a. electronic input files for both the intact fuel criticality model and the bounding and representative degraded criticality model. If different models were constructed for the in-package, near-field, and far-field criticality cases, provide the bounding criticality model for each case. The files should be in a form that is suitable to being run.

b. the list of critical benchmark experiments (laboratory critical experiments) and commercial reactor criticals (and, if they are not contained in the International Handbook of Evaluated Criticality Safety Benchmark Experiments, a reference to the source of the experiments) applicable to each criticality model submitted.

c. electronic input files for at least one case from each laboratory critical experiment and one commercial reactor critical used to validate the criticality models submitted. The filers should be in a form that is suitable to being run.

d. justification that the critical experiments are applicable to the system whose models are submitted (e.g., tables comparing the relevant parameters of systems to those of the applicable laboratory critical experiments or commercial reactor criticals, the results of TSUNAMI runs, or other justification).

e. The k_{eff} values for each criticality model submitted, and the bias and uncertainty, and area of applicability, for the laboratory critical experiments and commercial reactor criticals used to validate them.

The next two RAIs pertain to CSNF and the need for justification for the use of burnup credit in DOE's postclosure criticality calculations.

RAI #25: Justify the list of principal isotopes used and show that the abundance of those isotopes is conservative (both for initial emplacement and over the post-closure period of concern) for the calculation of $k_{eff.}$

RAI #26: Demonstrate that both the depletion (calculation of isotopic abundances) and the reactivity (calculation of k_{eff}) portions of the calculational methodology have been appropriately validated. Demonstrate the applicability of the experimental data and provide the bias and uncertainty for both portions of the methodology (or for the combined depletion and reactivity methodology).

RAI #27: For naval spent nuclear fuel (NSNF), justify your assertion that it is bounded by CSNF. Explain what you mean by bounding, and provide the technical basis for making this conclusion since reported probability of criticality per waste package is about one order of magnitude higher for naval than for other types of fuel. In lieu of providing this justification, you may provide the information that is requested in the preceding questions for DOE SNF and CSNF.

The next six RAIs pertain to the DOE analysis of CSNF in Attachment III, "LBTL Calculation and ROA Determination for LWR SNF," of the Criticality Model document:

RAI #28: Justify the use of nitrate solution benchmarks, given that the most likely form of material will be metal-water or oxide-water systems. It is not clear why these are applicable to disposal conditions.

RAI #29: UO_2 and mixed oxide (MOX) lattice critical experiments were combined based on a statistical test (Student's T-Distribution). This test is purely statistical and does not take into account differences in the physics of the two systems. Justify the combining of these data rather than analyzing the bias and uncertainty for these two systems separately.

RAI #30: Justify not performing parameter trending as a function of isotopic abundances (^{235}U, ^{239}Pu, or Pu/U wt%). Enrichment and isotopic abundance are typical trending parameters, the use of which could reveal biases as a function of the isotopic content of the SNF.

RAI #31: Justify not performing bias trending as a function of different absorber or other structural materials. There is frequently a bias effect due to the use of different material cross sections.

RAI #32: While several different trending parameters are used, several of the parameters are essentially duplicative (i.e., pitch/diameter, pitch, water-to-fuel ratio, average energy of neutrons causing fission, and average lethargy of fission; these are essentially all indicators of the level of thermalization of the system). Given this, justify DOE's assertion that sufficient trending parameters have been used to fully characterize the bias across the validated area of applicability.

RAI #33: All the laboratory critical experiments involve fresh fuel isotopics. Justify why they are applicable to systems involving either newly-irradiated or significantly aged (over geological time frames) CSNF. Similarly, demonstrate why the commercial reactor criticals are applicable to systems with significantly aged CSNF.

RAI #34: For each of the nine types of DOE SNF, CSNF, and NSNF, provide summary tables of the most significant parameters (enrichment and other isotopic proportions, including any isotopes used for burnup credit, physical and chemical form of fissionable material, geometric shape and dimensions of fissionable material and waste package, moderator-to-fuel ratio, reflection conditions, type and proportion of credited neutron absorbers, and energy spectrum) assumed in the bounding normal condition model and the bounding abnormal condition models.

In addition, provide the expected normal condition and most reactive credible abnormal condition values for each of these parameters, to enable an assessment of the degree of conservatism in the criticality calculations.

In addition, estimate the margin in k_{eff} resulting from conservatism between the two sets of parameter values. This estimation should preferably be done for each parameter in the table, but it is acceptable to estimate the margin resulting from the combination of conservatism in individual parameters. If this cannot be done quantitatively, provide a qualitative discussion of the physical factors that ensure that the calculational results are conservative.

RAI #35: For DOE SNF, estimate the amount of conservatism resulting from assuming fresh fuel, instead of spent fuel, isotopic abundances.

RAI #36: For CSNF, justify the conservatism (by providing your analysis) in the assignment of burnup credit, including the margin in k_{eff} resulting from conservative depletion parameters (fuel and moderator temperature, moderator density, boron concentration, power history, axial burnup profiles, assembly average burnup, enrichment, burnable poison and control rod insertion assumptions, etc.). Discuss the conservatism relative to the uncertainty in the depletion parameters. Justify in particular the value of Δk_{ISO} and the burnup uncertainty of 5% as used in loading curves.

RAI #37: Demonstrate that the nine DOE SNF representative fuels bound all types of fuel in their groups that could be emplaced in the repository. Demonstrate that the intact and degraded configurations modeled bound the worst case credible abnormal conditions in the HLWR, for in-package, near-field, and far-field criticality.

RAI #38: Explain and justify DOE's assertion in CRWMS M&O (2003) that "there is no risk associated with a subcritical event." This is the only documented justification for the zero margin of subcriticality for postclosure criticality. In particular, explain the following:

a. If the "no risk" refers to the <u>probability</u> of criticality, explain how this is the case, given that criticality calculations are only performed for configurations that cannot be screened out based on probability.

b. If "no risk" refers to the <u>consequences</u> of criticality, explain why this is the case, given that subcriticality is used (as one of several screening criteria) to decide which events will be included in the consequence assessment. This could lead to a circular argument.

c. Justify why a zero margin provides adequate assurance that systems evaluated to be subcritical actually are subcritical. If there is a regulatory reason for criticality calculations to be performed, there is presumably a need to ensure subcriticality with a high degree of confidence.

RAI #39: The current Topical Report (YMP/TR-004Q) states (p.1-5) that "The probability of one criticality occurring will be less than one over the entire repository for the first 10,000 years." The prior version of the topical report, for which the staff provided a Safety Evaluation Report (NRC, 2000, page 19), stated: "…a criticality frequency of 10^{-4} per year for all combinations of waste packages and waste forms." Are the two statements equivalent? If not, please address the differences and quantify the current version's probability number

RAI #40: DOE has not justified its selection of zero for postclosure criticality administrative margin. SNF systems that have k_{eff} values significantly below 1.0 already have sufficient margin, and are not a concern. Provide the approximate proportion of the spent fuel inventory that exceeds a k_{eff} value (including uncertainties) of 0.98 (the minimum that has historically been considered acceptable for other NRC-regulated activities), for each of the nine types of DOE SNF, and CSNF. This should be done for both the intact and degraded fuel cases. For all those calculations that exceeded this k_{eff} value, provide a description of the system, as well as the initially estimated probability and calculated k_{eff} value. For configurations close to the k_{eff}

limit that have degraded geometries, justify the margin, given potential uncertainty about the most reactive form and geometry.

RAI #41: Estimate the effect on the criticality dose if those waste configurations screened out on the basis of subcriticality had not been screened out. That is, determine how much of a difference it would have made to the end result if a subcritical margin of 0.02 were used instead of 0? If a subcritical margin of 0.05 were used?

RAI #42: Qualitatively describe (i.e., without providing specific likelihood numbers) the factors that ensure a low likelihood of achieving the bounding in-package, near-field, and far-field criticality configurations. Examples may include physical laws, geological and hydrological characteristics of the site, or any other phenomena that render the modeled conditions as having a very low likelihood.

RAI #43: Provide information on how “unqualified” (i.e., with respect to the loading curve requirements) assemblies will be disposed of. Provide estimate of probability of criticality for the waste packages containing “unqualified” commercial assemblies accounting for degradation processes and manufacturing errors for any additional neutron absorbers to be used in these waste packages. Justify that the probability of criticality calculated for waste packages containing “unqualified” assemblies would not affect overall repository probability of criticality.

References

Bechtel SAIC Company, LLC. “Commercial Spent Nuclear Fuel Waste Package Misload Analysis.” WHS–MD–000003. Rev. 00A. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2005.

CRWMS M&O. “Disposal Criticality Analysis Methodology Topical Report.” YMP/TR–004Q. Rev. 00. ADAMS Accession No. ML003742456, LSN Accession No. DEN001434519. Las Vegas, Nevada: CRWMS M&O, Yucca Mountain Site Characterization Office. 1998.

CRWMS M&O. “Waste Package Misload Probability.” CAL–WHS–MD–000001, Rev. 00. Las Vegas, Nevada: DOE, Office of Civilian Radioactive Waste Management. 2001.

CRWMS M&O. “Disposal Criticality Analysis Methodology Topical Report.” YMP/TR–004Q. Rev. 02. ADAMS Accession No. DOC.20031110.0005. Las Vegas, Nevada: CRWMS M&O, Yucca Mountain Site Characterization Office. 2003.

Sandia National Laboratories. “Screening Analysis of Criticality Features, Events, and Process for License Application.” ANL–DS0–NU–000001. Rev. 00. 2008screen.

Sandia National Laboratories. "Features, Events, and Processes for the Total System Performance Assessment: Analyses." ANL–WIS–MD–000027. Rev. 00. Las Vegas, Nevada: Sandia National Laboratories. 2008feps.

Sandia National Laboratories. "Loading Curve Sensitivity Analysis. "ANL-EBS-NU-000010 REV00. 2008loading.

Sandia National Laboratories. "Analysis of Mechanisms for Early Waste Package/Drip Shield Failure". ANL–EBS–MD–000076 Rev 00. Las Vegas, Nevada: Sandia National Laboratories. 2007.

Sandia National Laboratories. "In-Package Chemistry Abstraction." ANL-EBS-MD-00037 REV 04 AD 01. 2007inpchem.

FEP 2.2.08.03.0A Geochemical Interactions and Evolution in the SZ

The FEP 2.2.08.03.0A Geochemical Interactions and Evolution in the SZ is excluded from the performance assessment model based on low consequence (SAR Section 2.2 Table 2.2-5; SNL, 2008). The staff considers that the technical bases of the screening argument are not sufficient to support exclusion of the FEP from the performance assessment model.

RAI #44: Assess the consequence of temporal changes in chemical composition of the groundwater on radionuclide concentrations resulting from changes in sorption/desorption reactions in the saturated zone. This information is needed to verify compliance with 10 CFR 63.114 (e).

Basis: The performance assessment model assumes constant K_ds at all locations in the saturated zone for each individual realization. Consequently, the effect of temporal changes in chemical composition of the groundwater on radionuclide concentrations in the saturated zone is not considered in the performance assessment model. The effect of temporal variability in K_d on radionuclide concentrations has not been evaluated in the screening argument for the FEP 2.2.08.03.0A Geochemical Interactions and Evolution in the SZ. Spatial variations in groundwater compositions can produce temporal variations when water moves along flowpaths. The FEP screening argument, however, does not assess the impact of the temporal variation of bulk water chemistry on radionuclide concentrations arising from changes in sorption/desorption reactions in the saturated zone.

References:

SNL. 2008. "Features, Events, and Processes for the Total System Performance Assessment: Analyses." ANL–WIS–MD–000027. Rev. 00. ACN 01, ERD 01. Las Vegas, Nevada: Sandia National Laboratories.

SNL. 2007. "Saturated Zone Site-Scale Flow Model." MDL–NBS–HS–000011. Rev. 03. ACN 01, ERD 01, ERD 02. Las Vegas, Nevada: Sandia National Laboratories.