UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

September 18, 2012

Mr. R.W. Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: INTERIM STAFF GUIDANCE 8, REVISION 3, "BURNUP CREDIT IN THE CRITICALITY SAFETY ANALYSES OF PWR SPENT FUEL IN TRANSPORTATION AND STORAGE CASKS"

Dear Mr. Borchardt:

During the 597th meeting of the Advisory Committee on Reactor Safeguards, September 6-8, 2012, we completed our review of Interim Staff Guidance (ISG)-8, Revision 3, "Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transportation and Storage Casks." Our Radiation Protection and Nuclear Materials Subcommittee also reviewed this matter during a meeting on July 10, 2012. During these meetings, we had the benefit of discussions with representatives of the NRC staff, the Electric Power Research Institute, and the Nuclear Energy Institute. We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATION

1. The staff has revised ISG-8 to include provisions to:

    a) allow for the addition of 20 actinides and fission products in the determination of burnup credit,
    b) extend credit to 60 gigawatt-days per metric ton uranium (GWd/MTU) assembly-average burnup, and
    c) provide an option for misload analyses with additional administrative loading procedures in lieu of assembly burnup measurements.

2. These changes enable more realistic assessments of burnup credit and ISG-8, Revision 3, should be issued.

3. We support and encourage the staff efforts to communicate to licensees and certificate holders the importance of systematic development, maintenance, and use of improved cask loading plans and procedures to prevent misloads.

BACKGROUND

Originally, criticality safety analyses for commercial light water reactor spent nuclear fuel (SNF) transport and storage casks assumed the SNF to be "fresh" (unirradiated) with uniform isotopic composition. This fresh-fuel assumption provided a simple bounding approach to the criticality analysis and eliminated the need for elaborate analyses based on the fuel operating history. This assumption ignored the net decrease in the inventory of fissile materials in SNF as a result of fissioning. The assumption was conservative but resulted in a significant reduction in SNF capacity for a given cask volume. To achieve higher waste loading capacity, cask designers introduced a "burnup credit" approach that accounts for the reduction of fissile materials and the accumulation of actinides and fission products that absorb neutrons, which permitted elimination of flux traps (i.e., spacing and additional neutron absorber plates between fuel assemblies).

In 2002, the staff issued Revision 2 to ISG-8. This revision provided guidance on (1) criteria to determine whether pressurized water reactor (PWR) SNF is eligible for burnup credit consideration and (2) experimental data required and the general approach to be taken in determining bias and uncertainty in the analysis codes. ISG-8, Revision 2, only credited actinides and was based on available validation data at the time of approval. Furthermore, ISG-8, Revision 2 specified confirmatory pool-side burnup measurements as an acceptable method for the prevention of misloads.

In 2007, the Commission tasked the staff to focus its effort on using burnup credit as a means to insert more realism into SNF transportation cask criticality analyses.

In 2008, a letter from the Advisory Committee on Nuclear Waste and Materials to the NRC Chairman included a recommendation that the staff take a risk-informed approach to evaluating burnup credit that included consideration of realistic and credible scenarios, probabilities, and consequences.

DISCUSSION

ISG-8, Revision 3, incorporates the results of burnup credit-related research that has been conducted since Revision 2 was issued. ISG-8, Revision 3, includes three major changes in the recommendations for reviewing burnup credit applications for SNF transportation and storage casks: (1) optional credit for fission product and minor actinide neutron absorbing isotopes in the SNF composition, (2) an increase in the assembly-average burnup recommended for burnup credit, and (3) misload analyses and additional administrative procedures in lieu of a burnup measurement at the time of loading.

The new guidance incorporates credit for the actinides and fission products listed in Tables 1 and 2 and extends burnup credit to fuel assemblies with average burnup as high as 60 GWd/MTU, from the current limit of 50 GWd/MTU. Approximately 75% of the reactivity reductions obtained using the new guidance are due to crediting actinide buildup and the remaining 25% to fission products.

Table 1: Recommended set of nuclides for actinide-only burnup credit

^{234}U	^{235}U	^{238}U
^{238}Pu	^{239}Pu	^{240}Pu
^{241}Pu	^{242}Pu	^{241}Am

Table 2: Recommended set of additional nuclides for actinide and fission product burnup credit

^{95}Mo	^{99}Tc	^{101}Ru	^{103}Rh
^{109}Ag	^{133}Cs	^{147}Sm	^{149}Sm
^{150}Sm	^{151}Sm	^{152}Sm	^{143}Nd
^{145}Nd	^{151}Eu	^{153}Eu	^{155}Gd
^{236}U	^{243}Am	^{237}Np	

Expanding Technical Basis for Burnup Credit

The most significant challenge to expanded burnup credit has been the validation of depletion and criticality calculations. Applicants and staff have been constrained by both a paucity of data and lack of a clear technical basis or approach for use of the available data. Oak Ridge National Laboratory (ORNL) gained access to data from a series of actinide critical experiments performed by the French Institut de Radioprotection et de Sûreté Nucléaire at their Valduc critical experiment facility. ORNL evaluated these data and concluded that they substantially strengthen the technical basis for actinide criticality validation.

Using the revised guidance, an applicant may credit the minor actinide and fission product nuclides listed in Table 2, provided the bias and bias uncertainty associated with the major actinides are determined. A conservative estimate for the combined bias and bias uncertainty associated with minor actinide and fission product nuclides of 1.5% of their worth may be used. This estimate is appropriate provided an applicant:

- uses the Standardized Computer Analysis for Licensing Evaluation (SCALE) code system with the Evaluated Nuclear Data Files (ENDF)/B-V, ENDF/B-VI, or ENDF/B-VII cross section libraries,
- uses the appropriate initial assumptions and code modeling as provided in Appendix A of ISG-8, Revision 3,
- justifies that its cask system design is similar to the system design used as the basis for the NUREG/CR-7109 criticality validation, and

- demonstrates that the combined minor actinide and fission product worth is no greater than 10% in k_{eff}.[1]

For code systems other than SCALE with the ENDF/B-V, ENDF/B-VI, or ENDF/B-VII cross section libraries, a conservative estimate for the combined bias and bias uncertainty associated with minor actinide and fission product nuclides of 3.0% of their worth may be used.

ORNL also developed a new validation technique for depletion analysis which accounts for bias and bias uncertainty. Reference values for bias and bias uncertainty found in NUREG/CR-7108 may be used provided an applicant:

- uses the same code and cross section library as was used in NUREG/CR-7108,
- uses the appropriate initial assumptions and code modeling as provided in Appendix A of ISG-8, Revision 3,
- justifies that its design is similar to that used as the basis for the NUREG/CR-7108 isotopic depletion validation, and
- limits credit to the specific nuclides listed in Tables 1 and 2.

<u>Misloading Fuel in Casks</u>

Misloading of underburned fuel assemblies causes an increase in reactivity. The importance of these increases to criticality safety is dependent on several factors, but is dominated by the amount by which the actual assembly burnup is less than the minimum burnup value for loading acceptance and the position of the misloaded assembly in the cask.

During the staff's efforts to update the guidance they identified and evaluated misload or near-misload events. Cask loading activities rely on many human actions with associated opportunities for error. The staff has concluded that misload events are credible and not infrequent. Furthermore, based on event tree models and empirical data, the preponderance of misloads were found to be caused by errors in the planning process for fuel movement and were likely to involve multiple assemblies and casks. While none of the misloads and near-misloads created a criticality challenge, these events revealed a need for improved planning processes.

ISG-8, Revision 3, includes an option for misload analyses, accompanied with additional administrative loading procedures that may be used in lieu of assembly burnup measurements specified in ISG-8, Revision 2. ISG-8, Revision 3, recommends that the applicant evaluate two misload cases: (1) a single severely underburned fuel assembly chosen such that the reactivity of the fuel bounds 95% of the underburned fuel population with 95% confidence and (2) a group of moderately underburned fuel assemblies (at least 50% of the payload) such that the reactivity of the fuel bounds 90% of the total discharged fuel population.

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[1] The effective neutron multiplication factor (k_{eff}) is the ratio of the number of neutrons in one generation to the preceding generation for a finite reactor. If k_{eff} = 1, the reactor is critical.

We support and encourage the staff efforts to communicate to licensees and certificate holders the importance of systematic development, maintenance, and use of improved cask loading plans to prevent misloads.

Sincerely,

/RA/

J. Sam Armijo
Chairman

REFERENCES

1. Memorandum to Edwin M. Hackett, Draft Interim Staff Guidance Document 8, Revision 3, “Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks,” June 07, 2012 (ML12159A589)

2. Memorandum to Edwin M. Hackett, Draft Final Interim Staff Guidance Document 8, Revision 3, “Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks,” September 05, 2012 (ML12250A057)

3. NUREG/CR-7108, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Isotopic Composition Predictions,” April 2012, (ML12116A124)

4. NUREG/CR-7109, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Criticality (k_{eff}) Predictions,” April 2012, (ML12116A128)

5. Staff Requirements Memorandum SECY-07-0185, ”Moderator Exclusion in Transportation Packages,” December 18, 2007 (ML073520174)

6. Advisory Committee on Nuclear Waste and Materials letter to the NRC Chairman, “Burnup Credit for Design of Criticality Safety Systems in PWR Spent Nuclear Fuel Casks,” April 9, 2008 (ML081000050)

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Letter to R.W. Borchardt, EDO, from J. Sam Armijo, ACRS Chairman, dated September 18, 2012

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