Full Burnup Credit in Transport and Storage Casks: Benefits and Implementation

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Introduction

Assuming credit for the burnup in spent nuclear fuel (SNF)—that is, burnup credit—within criticality safety evaluation of transportation packages can increase package capacity, enhance flexibility for system operations, and significantly reduce overall system costs. The benefits of burnup credit and the technical issues associated with utilizing burnup credit in SNF casks have been studied in the United States for almost two decades. The issuance of the Nuclear Regulatory Commission (NRC) staff guidance for actinide-only burnup credit in 2002 was a significant step towards providing a regulatory framework for using burnup credit in transport and storage casks. However, adherence to the current regulatory guidance, which limits credit to actinides, enables only about 30% of the existing pressurized-water-reactor (PWR) SNF inventory to be transported in high-capacity (32-assembly) casks. Work has been done to demonstrate that the allowable inventory percentage could potentially increase to nearly 90% if credit for actinides and fission products were allowed (i.e., "full" burnup credit). Thus, ORNL has worked with the NRC, the Department of Energy Office of National Transportation (DOE/ONT), and the Electric Power Research Institute (EPRI) to coordinate a research program that will

1. obtain and evaluate experiment data to support a strong safety basis for fission product credit,
2. investigate unresolved technical issues associated with PWR full burnup credit, and
3. recommend approaches for boiling-water-reactor (BWR) burnup credit in transport and storage casks.

This paper will discuss the benefits of the research program and the results obtained to date.

Benefits

Historically, package designs for SNF were constrained by weight, thermal loading, external dose, and structural integrity. With the reduced thermal load and dose provided by a minimum 5-year cooling time for transport of SNF, it quickly became apparent in the 1980s that package capacity would often be limited by the conservative, yet simple, fuel assumption of un-irradiated fuel (i.e., no burnup credit) used in criticality safety evaluations. For PWR SNF, burnup credit eliminates the need for the relatively wide basket structures (flux traps) used for separation and criticality control, thus providing an important degree of flexibility to package designers. Elimination of the flux traps increases the capacity of PWR transportation packages by at least 30%.

A relatively simple cost analysis performed for this study uses the current capacity limit for the Yucca Mountain repository of 70,000 Metric Ton Heavy Metal (MTHM), the percentage of total MTHM from PWRs as of the end of 1998 (~64%), and the average number of PWR assemblies per MTHM to predict that ~100,000 PWR assemblies will need to be transported to the repository. Loading curves were obtained by plotting fuel assembly burnup vs. initial enrichment, which delineates the region of allowed burnups and initial enrichments that can be loaded in a cask and maintain the subcritical safety margin. Using these curves and assuming assemblies that cannot be accommodated in a 32-assembly cask are transported in a 24-assembly cask, it was estimated that full burnup credit can reduce the number of shipments by ~22% (~940 shipments). Actinide-only-based burnup credit reduces the number of shipments by only ~8% (~315 shipments). A survey of industry experts suggested an estimated cost-per-rail-cask shipment (freight and operational costs) ranging from $200K to $500K. Although the majority of those surveyed leaned toward the $500K/shipment value, a conservative estimate of $250K was adopted. Using this per-shipment estimate provides a cost savings (assuming shipments reduced by 625) of at least $156M that can be realized by establishing full burnup credit for SNF transportation. This cost-savings estimate is expected to increase with consideration of shipping legal-weight truck casks because (1) the increase in capacity is 100% (an increase from either 1 or 2 assemblies per package to 2 or 4 assemblies per package) and (2) the shipping costs are higher on a per-assembly basis. The full paper will provide results of a benefits analysis in which a wide range of cask sizes (from legal-weight truck casks to 125-ton rail casks) were considered to be available for shipment.

Implementation Plan

To support a criticality safety evaluation that provides the maximum credit from actinides and fission products requires a well-qualified data base of experimental information that can ensure reliable and accurate estimation of any bias and uncertainty resulting from the codes and data used to predict the system neutron multiplication factor, k-eff. Oak Ridge National Laboratory (ORNL) is seeking to obtain, and make available to industry, a "complete" set of critical experiment data and isotopic assay data that can be used to provide a straightforward estimate of the bias and uncertainty associated with the nuclear analysis method of choice.

Criticality experiments are being assessed and qualified using special computational tools developed at ORNL to help provide insights into the applicability of experiments to systems of interest. ORNL has procured rights to distribute proprietary critical experiments performed to support burnup credit validation for French fuel cycle applications. These experiments, many of which replicate cask-like conditions, were performed with lattices of pins fabricated with uranium and plutonium isotopic distributions that simulate spent fuel. Critical experiments within the International Criticality Safety Benchmark Evaluation Project are also being analyzed to assess their value in burnup credit validation. Additional experiments specific to potential fission product validation needs will be performed at Sandia National Laboratories as the needs are identified. The characteristics of commercial reactor critical configurations that might make them applicable to cask environments are also being investigated with the ORNL assessment tools. The results obtained to date from the critical experiment assessment will be presented in the full paper.

ORNL is also working to gather data from several international programs to provide the assay data needed for validation of codes used to predict the spent fuel isotopics. A comprehensive review of the available assay data still indicates a significant lack of data for key fission product isotopes. A plan to obtain appropriate data is being developed and will be discussed in the paper.

ORNL is also working with the European Union to improve the cross-section data for the key fission products of interest to burnup credit. The differential measurements and rigor used in the evaluation of fission-product cross sections has been far inferior to that applied to the major actinides. The goal is to improve the evaluation and measurement of each key fission product cross section as an aid to supporting the integral experiment data used for code validation.

The final portion of the project will be aimed at assessing the potential value of burnup credit for BWR SNF. The value of burnup credit will be less than that identified for PWR spent fuel because each BWR assembly is less reactive than a PWR assembly, thus making it easier to control the reactivity in a given cask volume. Depending on the value (e.g., benefit) to BWR burnup credit for transport and storage, ORNL will recommend an approach and associated technical basis that can be used with available experiment data. The full paper will discuss only the issues associated with BWR burnup credit and the approaches currently being considered for investigation.