SPENT-FUEL DECAY HEAT INVESTIGATIONS FOR BWR ASSEMBLIES USING BOTH ONE- AND TWO-DIMENSIONAL MODEL SIMULATIONS[a]

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INTRODUCTION

The Swedish Nuclear Fuel and Waste Management Company (SKB) is performing calorimetric measurements of decay heat for BWR and PWR assemblies at the Swedish Interim Spent Fuel Storage Facility, CLAB, at Oskarshamn. Oak Ridge National Laboratory (ORNL) has a collaborative role in this project and is performing model verification studies, and making independent decay-heat estimates, using ORNL codes. The CLAB measurements are being used to validate ORNL codes for high-burnup, high-enrichment fuel, and to support expansion of the NRC Decay-Heat Regulatory Guide 3.54 in addressing decay-heat issues for such fuel. This effort is ongoing but some preliminary measurements are now available. We will discuss model development efforts for these assemblies.

ASSEMBLY MODELING APPROACHES

The computational methods selected for the analysis of decay heat by SKB is the SCALE[1] 1-D depletion analysis sequence, SAS2H. The one-dimensional model treats assembly components as cylindrical zones and produces assembly-averaged nuclide concentrations and decay-heat estimates. With the limitation of a one-dimensional treatment, approximations are required in developing the model geometry of an assembly, particularly for the more complex and heterogeneous BWR assembly designs (e.g., the placement of zones representing water regions and burnable absorbers). Several different models are possible, and there currently exists no clear guidance on how best to construct models for the more complex designs. Different models were evaluated and were compared with explicit two-dimensional calculations performed using the discrete-ordinates transport module TRITON that is a recent addition to the SCALE system.

8×8 and 9×9 BWR Assemblies

Many BWR assemblies include fuel rods containing Gd_2O_3 as burnable absorber (BA) mixed with UO_2. To date, the general practice for modeling these assemblies is to place one of the gadolinium-containing rods in the central region of the model, and include a fraction of the full assembly containing the non-BA rods. For example, for an assembly with five BA rods, the assembly model would include one fifth of the fuel rods. In the case of assemblies that also include water holes the water must be added. This water is generally placed outside the subassembly model. The representation of an assembly continues with a zircaloy box and the channel moderator to the outside of this. In all cases, these materials were apportioned depending on the fraction of the assembly being modeled. The 9×9 assemblies contained four water rods and six BA rods. This approach was used to develop standard models for the 8×8 and 9×9 BWR assemblies.

Besides the standard approach described above, some alternative 1-D models were developed for these assemblies. The following alternative modeling approaches were evaluated:

1. A full assembly around a central water hole with the gadolinium as a narrow ring in the middle of the fuel zone.
2. Again, a full assembly around a water hole; however, the gadolinium is dispersed uniformly throughout the fuel zone.

By using a more comprehensive two-dimensional model, employing the TRITON code, it was possible to compare the different one-dimensional approaches to the explicit two-dimensional model. The results of these three modeling approaches for the 8×8-1 assembly are

[a] Support for this work was provided by the U. S. Nuclear Regulatory Commission under project number Y6517.

shown in Fig. 1. All models yield very similar results when compared to the 2-D model. The divergence of the results at larger cooling times reflects the differences in the prediction of higher actinide concentrations, particularly ^{244}Cm. The actinides are much more sensitive to differences in the models than are the fission products. The approaches involving the full assembly seem acceptable and yield results that are 2-3% higher than TRITON at long cooling times. For the 9×9-5 assembly, the full assembly also performed reasonably well. The use of a full-assembly model with a central water region is rational since in many BWR assembly designs the water rods, or channels, are typically clustered together.

The SVEA Assemblies

Two SVEA assembly types are being analyzed at CLAB: SVEA-64 and SVEA-100. These are 8x8 and 10x10 arrangements, respectively. These designs include a large water cross region. For analyses using 1-D models, these arrangements can be considered as being composed of four quadrants of 4x4 and 5x5 sub-assemblies, respectively. Burnup simulations were performed using the 1-D models by treating one quarter of the assembly, and were compared to explicit 2-D model results. These results will be discussed in the full presentation.

CONCLUSIONS

The different one-dimensional SAS2 results compare well with TRITON over the decay times studied as shown for an 8x8 BWR in Fig. 1. In general, the practice of subdividing the BWR assembly according to the number of BA rods has been found to overmoderate the assembly and overpredict the decay heat contribution from the actinides. This effect is a result of placing higher density channel moderator around the subassembly model. The alternative full assembly model was found to perform consistently well for most assembly configurations studied. This model provides an accurate presentation of the channel moderator and water rods, but sacrifices accuracy in representing the BA rods by effectively smearing the poison in the fuel. However, the effect of the BA rods is relatively short lived, whereas the effects of the water moderator are present throughout the exposure. It seems that all three one-dimensional approaches are reasonable for

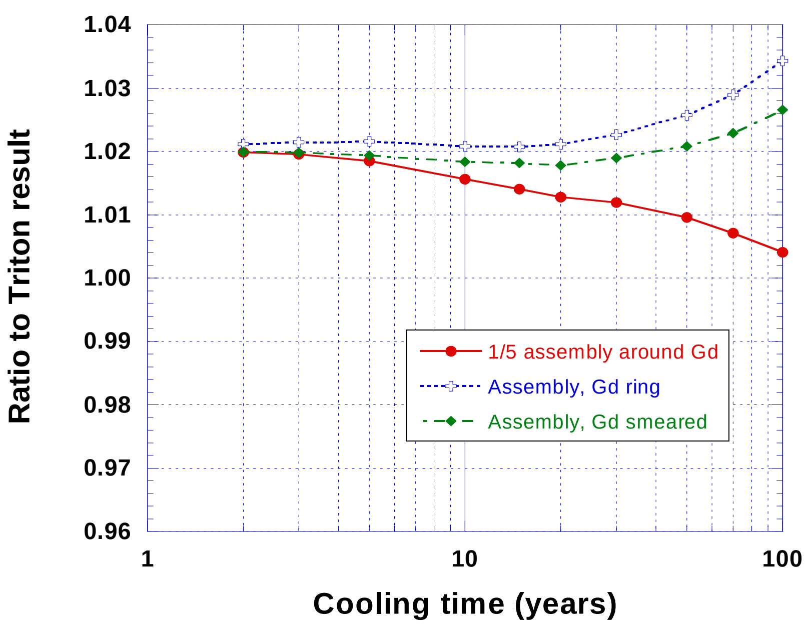

Fig. 1. Decay heat calculations for an 8x8 BWR using 1-D models as compared to a two-dimensional TRITON model. The three different one-dimensional modeling approaches are identified.

the case of this 8x8 BWR.

Two-dimensional methods have been used to evaluate several 1-D models and to give insight into the model limitations, particularly for the more difficult casesThe results seem to show that 1-D approaches yield reasonable decay-heat predictions.

REFERENCES

1. *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations*, NUREG/CR-0200, Rev. 7 (ORNL/NUREG/CSD-2/R7), Vols. I, II, and III, May 2004 (DRAFT). Available from Radiation Safety Information Computational Center at Oak Ridge National Laboratory as CCC-725.