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Computational Benchmark of SAS2D Against Spent Fuel Samples From the Takahama-3 Reactor

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Summary

The accurate prediction of nuclide compositions in spent nuclear fuel is necessary in order to evaluate important quantities, such as the neutron multiplication factor and radionuclide concentrations and toxicities for assessment of long-term environmental waste management concepts. The Oak Ridge National Laboratory (ORNL) has recently completed development of a two-dimensional (2-D) depletion sequence, SAS2D. Benchmark simulations have been performed with SAS2D against spent fuel radiochemical assay measurements from the Kansai Electric Ltd. Takahama-3 reactor.

The 2-D depletion sequence SAS2D [1] is a control module within the SCALE code system. SAS2D uses the 2-D arbitrary geometry, S_n theory code NEWT [2] to provide 2-D fluxes for a user-specified configuration. Depletion calculations are then performed for as many different materials as desired within the assembly configuration using multiple ORIGEN-S [3] calculations.

Takahama-3 is a pressurized-water reactor (PWR) with 17 × 17 fuel lattice assemblies. Spent fuel samples were obtained from two assemblies, NTG23 and NTG24, irradiated for 2 and 3 cycles, respectively. Both fuel assemblies contain 14 integral burnable gadolinia-bearing (Gd_2O_3) fuel rods containing 2.6 wt % ^{235}U and 6.0 wt % gadolinia while the standard fuel rods contain 4.11 wt % ^{235}U enrichment. Spent fuel samples were obtained from two standard fuel rods (SF95 and SF97) and one gadolinia-bearing fuel rod (SF96). A total of five samples were each taken from various axial locations of fuel rods SF95 and SF96, and six samples were taken from fuel rod SF97. Only one sample from each fuel rod was selected for this study. The SF95-3 fuel sample has a burnup of 35.52 GWd/MTU and was measured at an axial location of 88.1 cm (the distance is measured from the top of the active region of the fuel rod). The SF95-3 sample is taken from a fuel pin located in the corner of the fuel assembly, which had not been subject to local flux perturbations from the water holes or the burnable poison rods in the assembly during irradiation (i.e., all adjacent rods were standard fuel pins). The SF96-3 fuel sample has a burnup of 28.20 GWd/MTU and was extracted from an axial location of 85.6 cm. Note that the SF96-3 fuel sample was obtained from a gadolinia-bearing rod. The SF97-4 fuel sample has a burnup of 47.03 GWd/MTU and was located at an axial location of 183.9 cm, near the mid-plane of the rod. The SF97 fuel rod was a standard fuel rod, similar to SF95, located at the outer edge of the assembly. A detailed description of the Takahama-3 reactor and fuel design

specifications, as well as a summary of several basic parameters of the three measured spent fuel rods, can be found in Ref. 4.

Comparison of measurements and calculations of sample SF97-4 for various isotopes are presented in Figure 1 in terms of percentage difference between measured and calculated isotopic concentrations. The comparisons show that overall the SAS2D predictions agree very well with the measurements. Figure 1 also displays the results of previously performed calculations with the SAS2H and HELIOS code systems [4] for same fuel sample. It is interesting to note that the SAS2D prediction, for the most part, are more accurate than both SAS2H and HELIOS, especially for U and Pu isotopes. Similar trends were observed for the SF95-3 sample. Figure 2 displays the percentage difference between measured and calculated isotopic concentrations for sample SF96-3 (Gd-rod). While SAS2D shows better agreement than the SAS2H and HELIOS codes, there are some large differences between the calculated-to-experimental ratios for the Am and Cm isotopes.

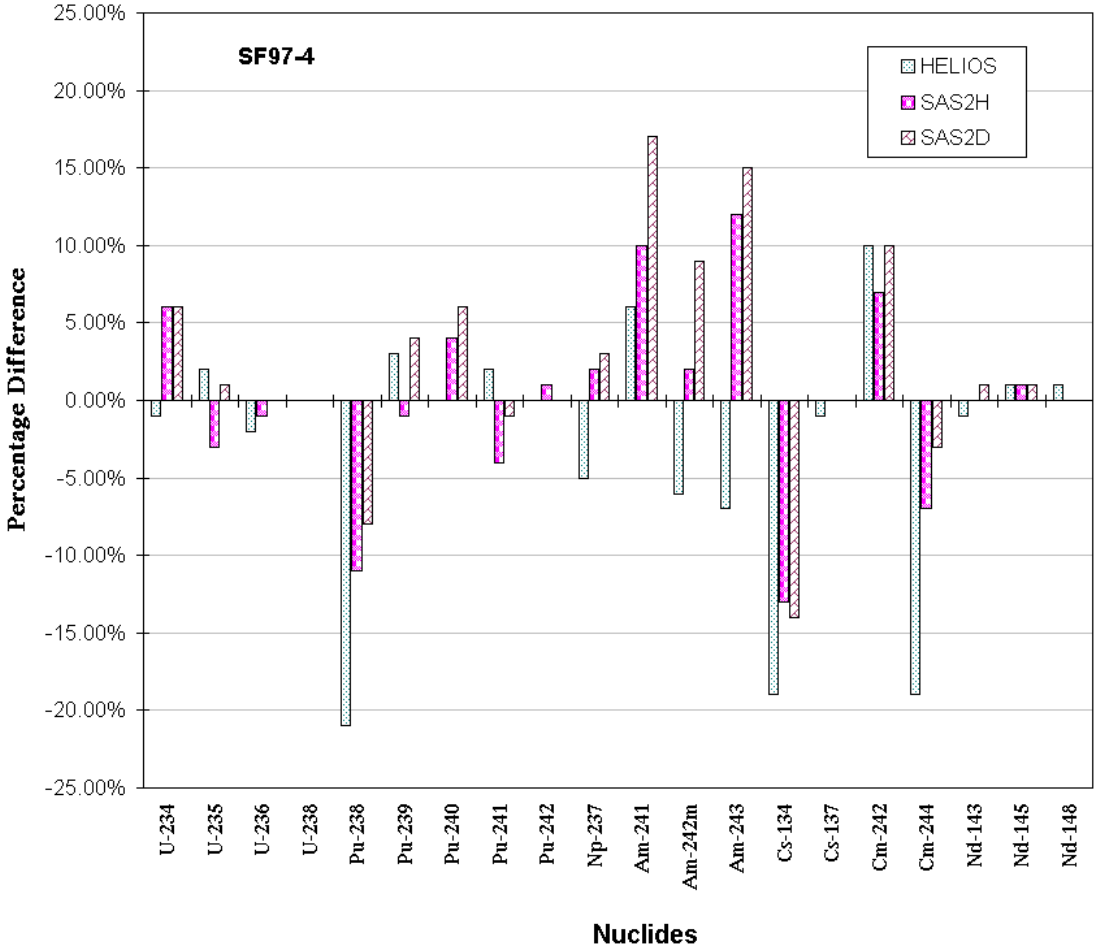

Figure 1. Percentage difference between calculated and measured nuclide concentrations for the SF97-4 fuel sample. The calculations were performed with the HELIOS, SAS2H, and SAS2D code systems.

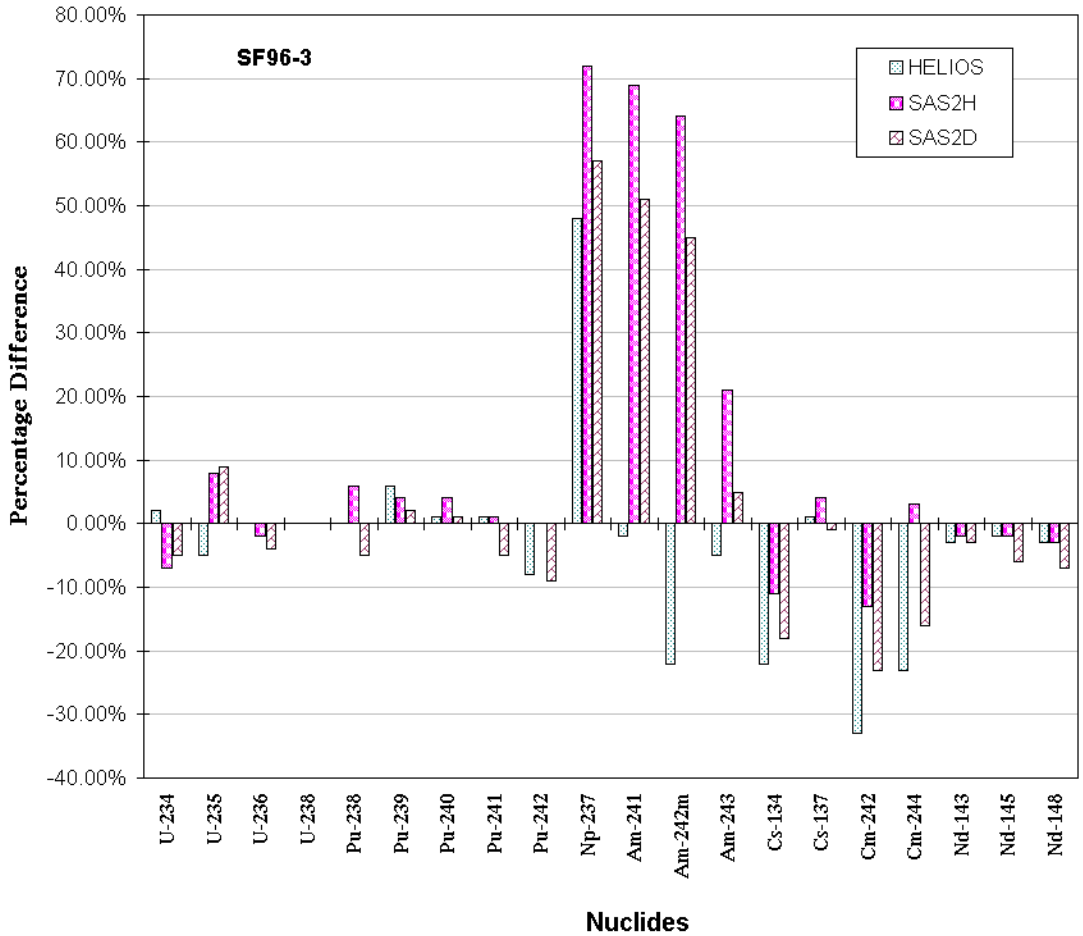

Figure 2. Percentage difference between calculated and measured nuclide concentrations for the SF96-3 fuel sample. The calculations were performed with the HELIOS, SAS2H, and SAS2D code systems. Note that the SF96-3 fuel sample is taken from a Gd-rod.

The radiochemical isotopic assay data for the Takahama-3 reactor have been applied to validate the isotopic predictions using SAS2D. The SAS2D predictions for the standard fuel samples SF95 and SF97 were in good agreement with the measurements. Further, the SAS2D predictions were on the similar level of accuracy as those of the SAS2H and HELIOS code systems. In fact, SAS2D proved to be more accurate in several cases, especially for most of the U and Pu isotopes. Future improvements of SAS2D include the usage of the CENTRM code [5], in lieu of the NITAWL sequence in the SCALE cross-section processing scheme, in order to provide resolution of spatially varying cross sections. This way spatially varying media (e.g., absorber rods) can be modeled more accurately, which should also reduce the differences noted with the SF96 Gd-rod sample.

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