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# SIMPLIFICATION OF MULTI-GROUP CROSS-SECTION PROCESSING FOR LARGE DEPLETION CALCULATIONS IN TRITON

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## ABSTRACT

TRITON is the primary lattice physics module of the SCALE codes system. Initially developed under US NRC funding for high fidelity mixed-oxide fuel assembly analysis, TRITON is being used internationally for a wide variety of applications. However, for large heterogenous lattice configurations, cross section processing required to obtain appropriately weighted burnup dependent cross sections can be a bottleneck in a calculation. To overcome this issue, a new approach to simplify cross section processing requirements for lattice depletion calculations in TRITON has been developed. This approach has been implemented and tested within TRITON, and found to result in very little loss of accuracy in the rigorous multigroup cross section weighting available within SCALE. Results are presented for the analysis of a 9x9 BWR lattice in which 41 independent depletion pin cells are tracked, and show that the simplified cross section processing option in TRITON results in a substantial reduction in computational time with very little loss of accuracy. The capabilities described herein are available within the Version 5.1 release of SCALE.

*Key Words*: TRITON, NEWT, Lattice Physics

## 1. INTRODUCTION

The T-DEPL sequence of the TRITON module [1] within SCALE code system [2] provides the ability to perform two-dimensional lattice calculations to provide cross sections and other lattice data for subsequent core simulator calculations [3]. TRITON provides automated, problem-dependent cross-section processing followed by calculation of the neutron multiplication factor for a two-dimensional system using NEWT. This functionality can be iterated in tandem with ORIGEN-S depletion calculations to predict isotopic concentrations, source terms, and decay heat as a result of time-varying fluxes calculated in a two-dimensional deterministic fashion. TRITON has been developed in part to support lattice physics calculations through cross section homogenization and collapse, with branch state capabilities.

In calculations for large, heterogeneous fuel assemblies, it is often necessary to individually track nuclide inventories in each fuel pin location; for strong poisons, rods must be depleted in rings to capture radial burnup effects. Although symmetry can often be used to reduce the number of pins tracked can still remain substantial, on the order of 20-30 pin cells. Although the SCALE system provides a rigorous mechanism for multigroup cross-section processing using the continuous energy solver CENTRM [4] for resolved resonance processing, this rigor has

associated with it a computational cost. Generally this computational burden is not significant for fresh fuel assemblies where no more than a handful of cells need be processed, the time required to process a large number of cells will often exceed the time required for the transport calculation itself.

This paper will describe a new approach developed for TRITON to reduce the computational burden associated with multigroup cross section processing, and greatly accelerate the process with little impact on accuracy.

## 2. APPROACH

In depletion calculations, multigroup cross sections change with depletion of the initial fuel and the buildup of higher actinides and fission products. The depletion approach in the TRITON control module in SCALE performs cross section updates with burnup in order to capture the effect of changing nuclide inventories as nuclear fuel is burned. However, it has been observed that macroscopic cross sections used in transport and depletion calculations are more sensitive to nuclide number densities that to the microscopic cross sections of the nuclides themselves. It was hypothesized that for *similar* fuel rods, cross section resonance processing could be simplified by performing calculations based on the average isotopic composition of each rod. The definition of a set of *similar* rods remained to be determined, but as a first guess it was assumed that rods of the same initial enrichment would be similar over the life of an assembly.

To put this hypothesis to a test, the TRITON sequence for depletion calculations, T-DEPL, was modified to separate cross section processing functionality from transport/depletion calculations. The ability was added to *assign* a set of mixtures in the transport and depletion phases to a single, representative mixture for cross section processing. The calculational procedure is illustrated in Figure 1. In effect, the code is used to process cross sections for a set of *representative* mixtures. Cross sections for these mixtures are duplicated for each *assigned* mixture. Transport and depletion calculations treat each mixture as distinct. At the end of each set of depletion calculations, the number densities for each set of assigned mixtures is averaged to update the number densities for the reduce set of representative mixtures. This process is repeated as TRITON performs periodic cross section updates during a depletion calculation.

## 3. RESULTS

To test the accuracy of this approach, a depletion calculation was set up based on the Next Generation Fuels benchmark specification [5] for a conceptual $UO_2$-fueled 9x9 BWR design. The fuel lattice is comprised of 5 pin enrichments including a gadolinum-bearing fuel rods, in 74 fuel rod positions. Using symmetry, this can be reduced to 41 independent locations. However, because of the need to deplete gadolinium rods in rings, a total of 73 independently depleted mixtures are modeled, using 5 concentric rings of fuel in each of 8 independent poison rod positions.

Two TRITON depletion models were developed; the first used the standard approach, in which pin cell calculations are performed for each of 41 unique pin locations. In the second model, cell processing was performed for only 5 pin cells, representing the 41 unique fuel rod designs

present. Both models perform transport and depletion calculations for all 73 independent mixtures.

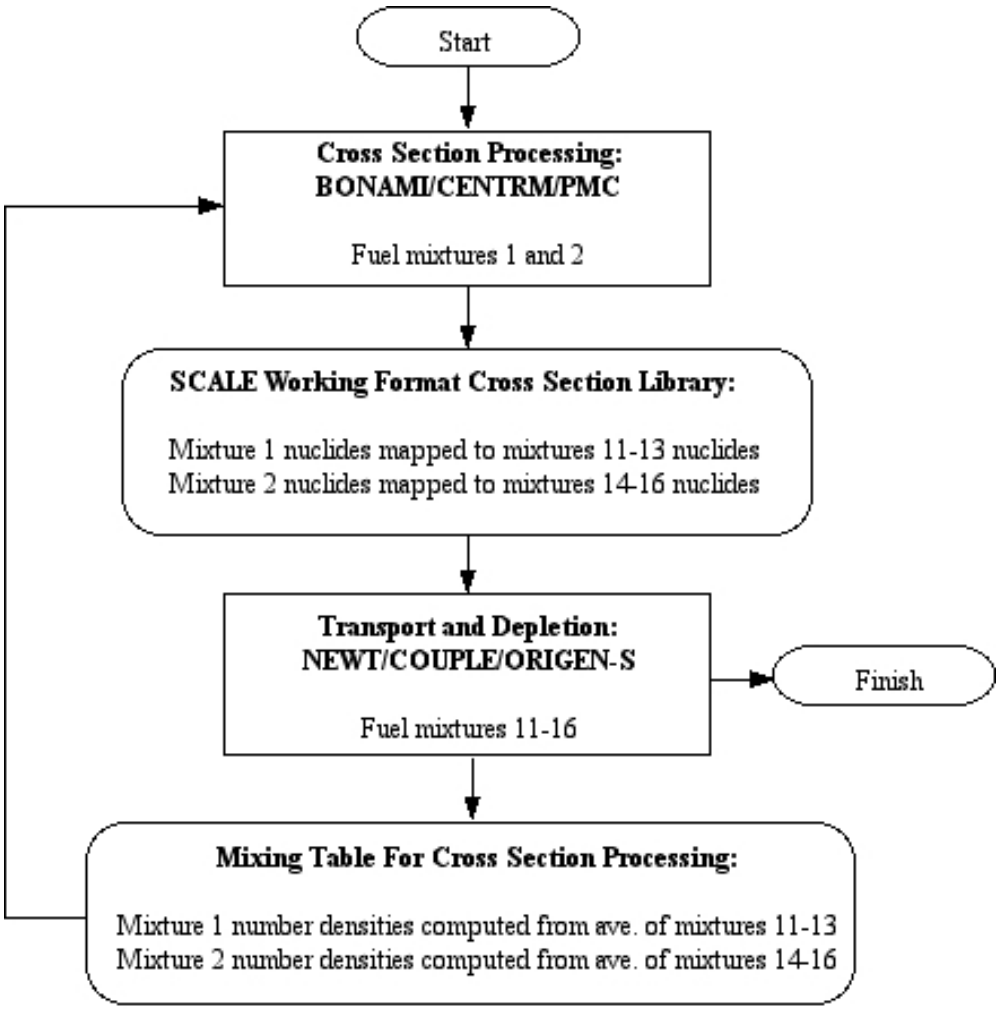


**Figure 1. Schematic illustration of TRITON process for reduced cross section processing**

Figure 3 shows $k_{eff}$ calculated as a function of burnup for both models. The results are indistinguishable. Hence, the percentage difference between the two is also shown on the same plot. The magnitude of the difference between the two $k_{eff}$ values remains below 0.02% over the entire cycle, with error increasing and peaking (and changing signs) as the gadolinium present in the poison rods is depleted. After full Gd depletion, the difference between the two methods decreases to effectively zero. Comparison of predicted nuclide number densities show the same trends and error of the same magnitude. However, the computational time for the simplified approach required only 18% of the time required for the explicit model – a speedup of 550%.

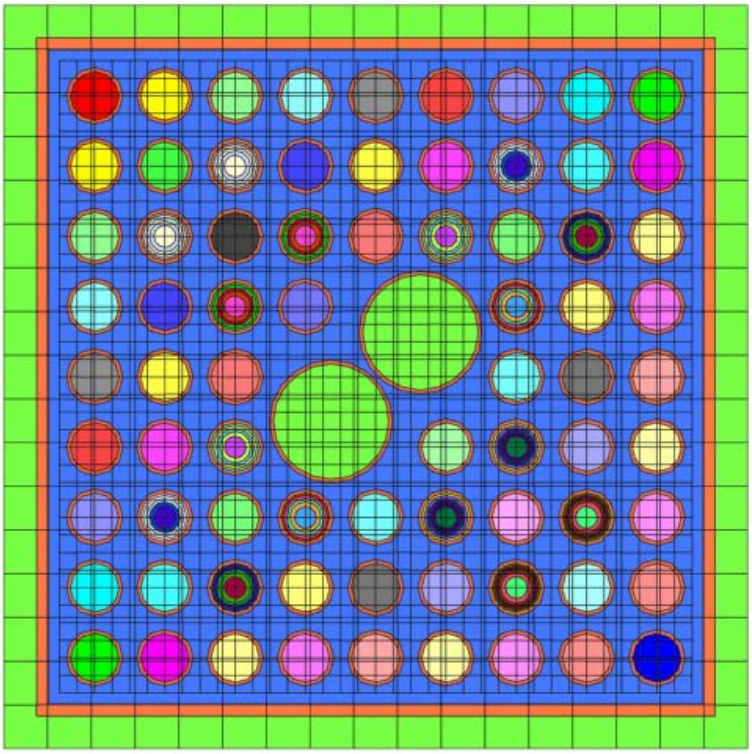

**Figure 2. NEWT Model for 9x9 BWR Depletion Calculation**

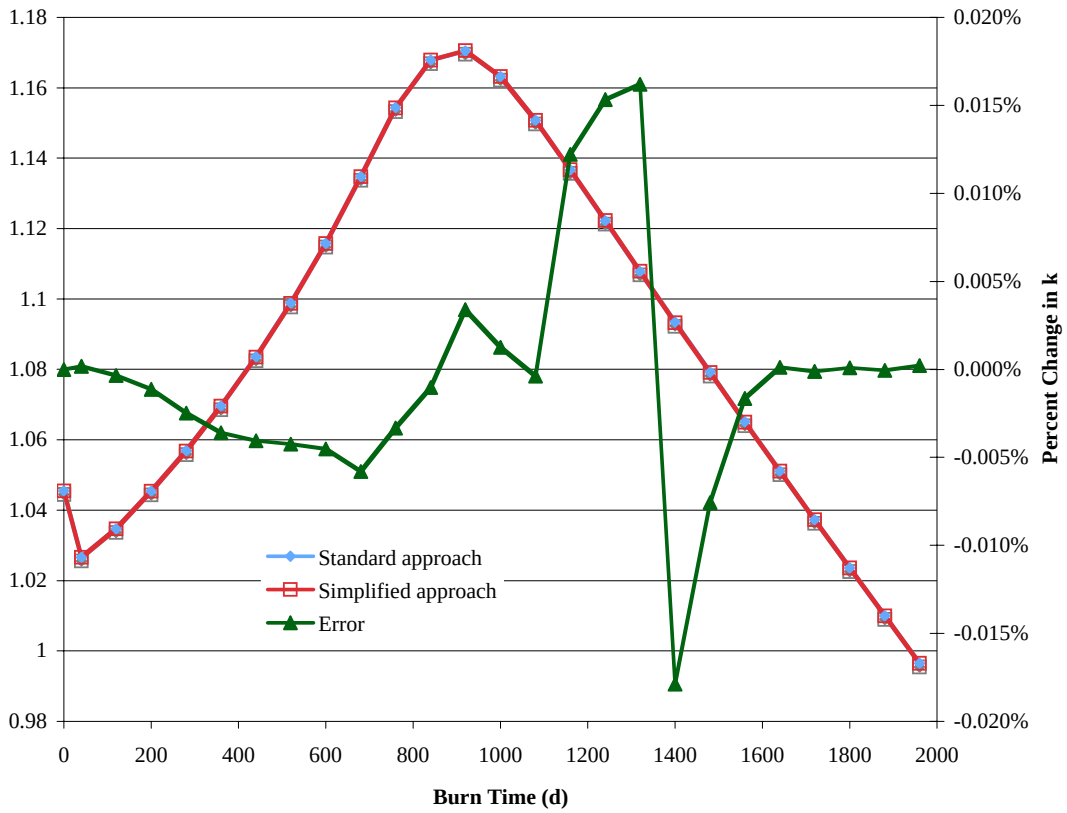


**Figure 3. Results of BWR Depletion Calculations**

## 4. CONCLUSIONS

The results provided here clearly demonstrate that the simplified approach for cross section processing recently implemented in the TRITON module within SCALE 5.1 provide substantial benefit in terms of computational requirements without a significant reduction in accuracy. This is a first phase of ongoing research at the Oak Ridge National Laboratory in methods to improve performance of TRITON for large scale depletion analysis, so that the high-fidelity resolution of TRITON calculations can be used for detailed lattice calculations in a computationally efficient manner.

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