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SMORES — A New SCALE Sequence for the Determination of Bounding Curves and Data

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I. INTRODUCTION

This paper describes the new prototypic sequence that has been added to the SCALE[1] (Standardized Computer Analyses for Licensing Evaluation) computer code system as an initial product of Subtask 1 of the Applicable Ranges of Bounding Curves and Data (AROBCAD) Task that was one of the seven technical task areas of the U.S. Department of Energy (DOE) Nuclear Criticality Safety Program.[2]

II. METHOD

The new SCALE control module SMORES (SCALE Material Optimization and REplacement Sequence) was developed to automate the problem-dependent cross-section preparation and one-dimensional (1-D) transport calculations to perform subsequent system optimization.[3]

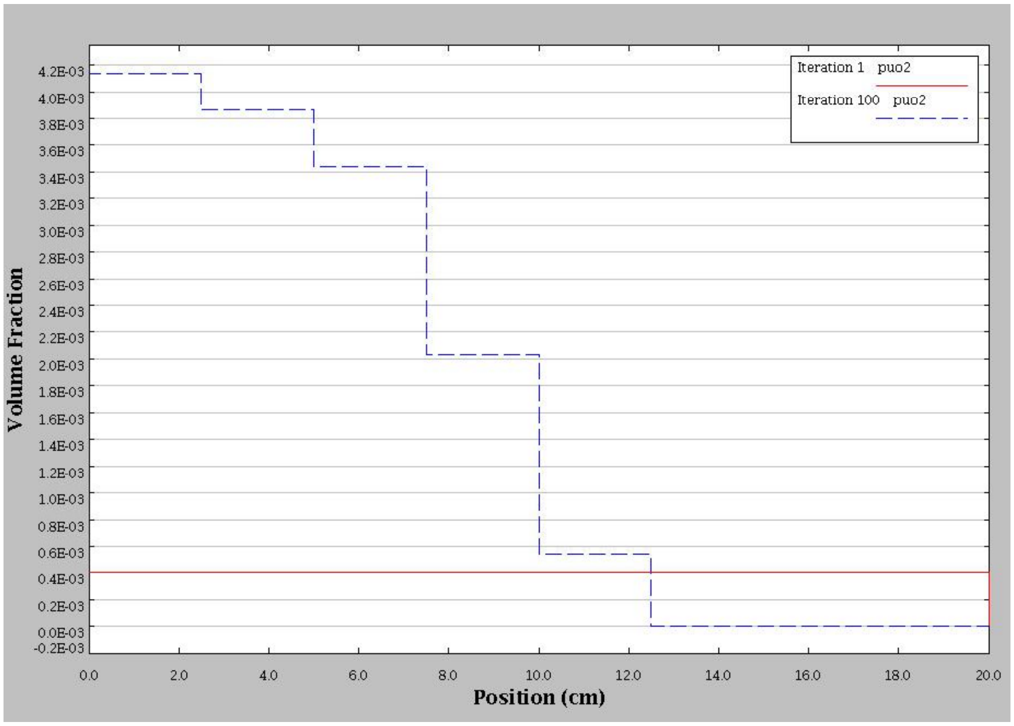
The SMORES module consists of three major steps: (1) preparation of the problem-dependent cross sections and mixing table used for the transport and optimization calculations, (2) execution of a 1-D neutron transport code to calculate the angular forward and adjoint fluxes, and (3) calculation of effectiveness functions and optimization of the system with respect to a parameter, either k_{eff} of a system, or minimum amount of fissile material in a system that will yield a desired k_{eff}. The cross sections are processed using either BONAMI/NITAWL-III modules or BONAMI/CENTRM/PMC modules of SCALE. BONAMI performs resonance self-shielding calculations for materials having Bondarenko data, while NITAWL-III applies the Nordheim resonance self-shielding correction to materials having resonance parameters. CENTRM/PMC calculates fluxes using point-wise cross sections and generates flux-weighted multi-group cross sections. The processed cross sections are then used to create a self-shielded macroscopic cross-section library using the functional module ICE. The forward and adjoint neutron transport calculations of the system are performed using the XSDRNPM module. This module performs the 1-D criticality calculation that provides the neutron fluxes that are used to determine the effectiveness functions, as well as the k_{eff} of the current system. Finally, the SMORES sequence calls the SWIF functional module, which has been developed by the University of California, Berkeley, Nuclear Engineering Department, that optimizes a specified parameter (k_{eff} or minimum mass) by calculating effectiveness functions determined from first-order linear perturbation theory by using the fluxes calculated by XSDRNPM and problem-dependent cross sections. Since the optimization process is iterative, the above steps are repeated until convergence is achieved or a maximum number of iterations are reached.

III. ANALYSES

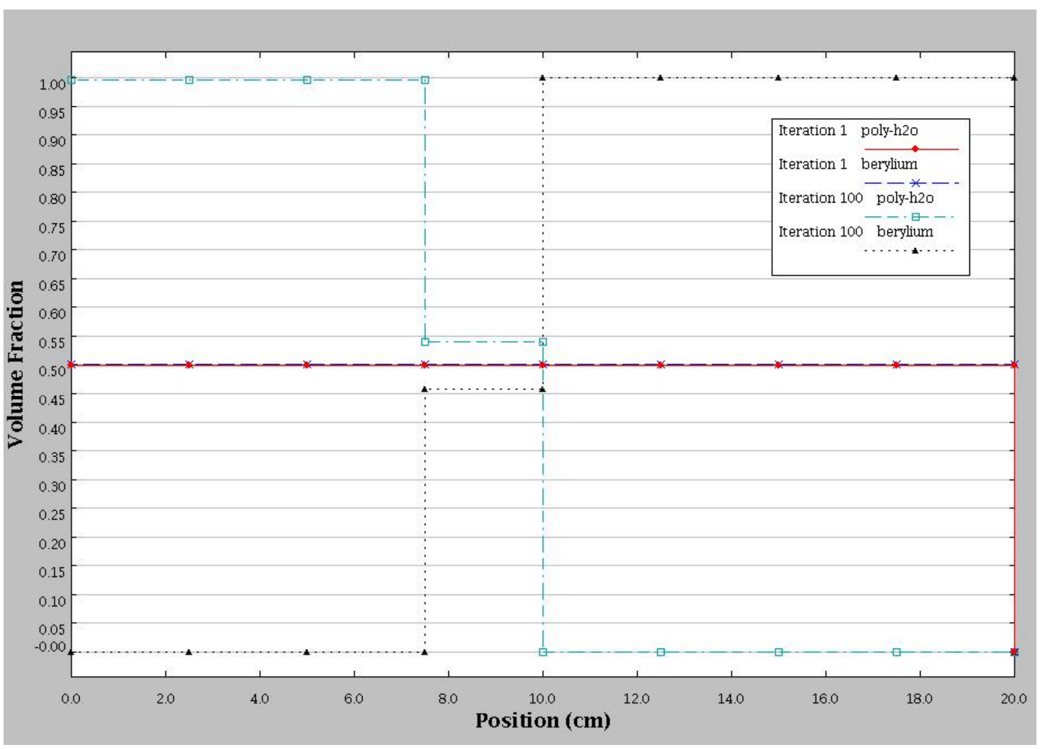
To illustrate the use of the new control program, a fissile spherical system has been modeled for determining maximum k_{eff}. The system core is 20-cm in radius and surrounded by 120-cm thick water reflector. The initial core contains a homogeneous mixture of $^{239}PuO_2$, polyethylene, and beryllium. The core is divided into eight equal-thickness zones. The initial and final volume fractions of the core constituents are shown in Figure 1. The k_{eff} of the system versus the iteration number is shown in Figure 2. As seen from the figures, initial k_{eff} that corresponds to the flat fissile material distribution is approximately 0.7. The final configuration, which eliminates the fissile material from the last three zones of the core, results in a k_{eff} of approximately 1.03. Figure 1(b) illustrates the effectiveness of polyethylene and beryllium as moderator and reflector. Beryllium is eliminated from the inner zones by replacing with polyethylene, which indicates that polyethylene provides better moderation. On the other hand, polyethylene is replaced with beryllium in the outer zones of the core, which indicates, as expected, that beryllium is a better reflector than polyethylene.

IV. REMARKS

Although SMORES is limited to 1-D geometries, it can provide very useful information about a fissile system for an analyst to make informed decisions in a much shorter time. The results of the sequence, however, need careful analysis by the user since the optimum configuration is not necessarily the configuration that results in the absolute highest k_{eff} or the absolute minimum critical mass.



(a) $^{239}PuO_2$ vs. position within the core



(b) polyethylene and beryllium vs. position within the core

Figure 1. Initial and final volume fractions of core constituents.

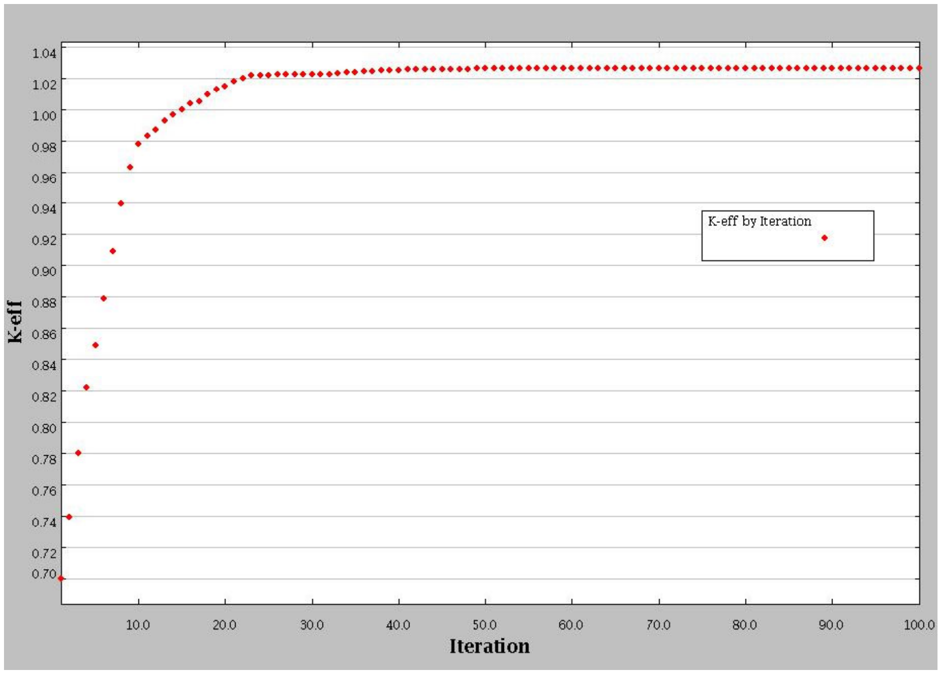


Figure 2. k_{eff} of the system vs. optimization iteration number.

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