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Computational Physics and Engineering Division

AN ADVANCED DETERMINISTIC METHOD FOR SPENT FUEL CRITICALITY SAFETY ANALYSIS

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DISCLAIMER

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Over the past two decades, criticality safety analysts have come to rely to a large extent on Monte Carlo methods for criticality calculations. Monte Carlo has become popular because of its capability to model complex, non-orthogonal configurations or fissile materials, typical of real-world problems. Over the last few years, however, interest in determinist transport methods has been revived, due shortcomings in the stochastic nature of Monte Carlo approaches for certain types of analyses. Specifically, deterministic methods are superior to stochastic methods for calculations requiring accurate neutron density distributions or differential fluxes. Although Monte Carlo methods are well suited for eigenvalue calculations, they lack the localized detail necessary to assess uncertainties and sensitivities important in determining a range of applicability. Monte Carlo methods are also inefficient as a transport solution for multiple-pin depletion methods.

Discrete ordinates methods have long been recognized as one of the most rigorous and accurate approximations used to solve the transport equation. However, until recently, geometric constraints in finite differencing schemes have made discrete ordinates methods impractical for non-orthogonal configurations such as reactor fuel assemblies. The development of an extended step characteristic[1] (ESC) technique removes the grid structure limitation of traditional discrete ordinates methods. The NEWT computer code, a discrete ordinates code build upon the ESC formalism, is being developed as part of the SCALE code system. This paper will demonstrate the

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power, versatility, and applicability of NEWT as a state-of-the-art solution for current computational needs.

DESCRIPTION

NEWT is built upon the theory described in Ref. 1, but several new features have been added to the method. First, the code has been completely rewritten in Fortran 90, allowing use of dynamically allocated data structures that can be tailored to match the unique form of arbitrary grid structures. The method has been updated to allow solution of concave cell structures, increasing the versatility for modeling curved surfaces. An automated grid generator has been developed, which allows rapid development of complex models. Figure 1 shows two grid structures generated by NEWT for the same configuration, a 1/4 BWR fuel assembly with central water hole and channel. The user need only supply the coordinates, material number, and sizes of each body, the size of the enclosing rectangle, and the number of grid divisions in each direction. NEWT runs within the SCALE code system; a simple two-step pseudo-sequence can be used to prepare AMPX-formatted cross-sections and material mixing tables from data supplied in CSASN format for use by NEWT.

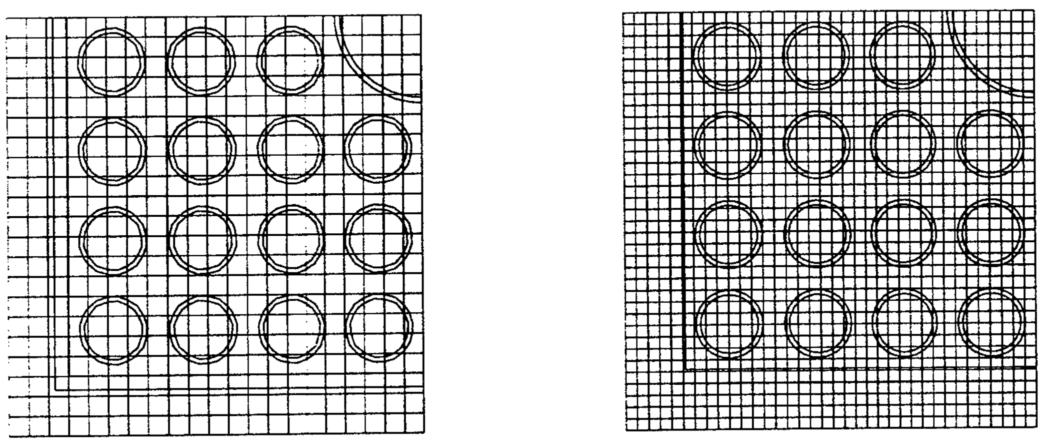

Fig. 1. NEWT 36×36 and 21×21 (nominal) grid structures with inlaid bodies.

RESULTS

As a test of the accuracy of NEWT relative to other computational methods, NEWT has been used to calculate the value of k_{eff} for a BWR-like computational benchmark[2] specified as part of an international burnup credit study coordinated by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD). The configuration of this benchmark is represented by the grid structure of Figure 1, with five different fuel enrichments. The benchmark was designed to compare both criticality and depletion methods. Results for zero burnup, based on supplied fuel specifications, are illustrated in Figure 2, for the various internationally contributed (preliminary) results. A variety of both codes and cross-section libraries were employed. Note that both KENO-V.a and NEWT are in close agreement, since both calculations are based on the same 44-group ENDF/B-V library, and employed identical cross-section processing.

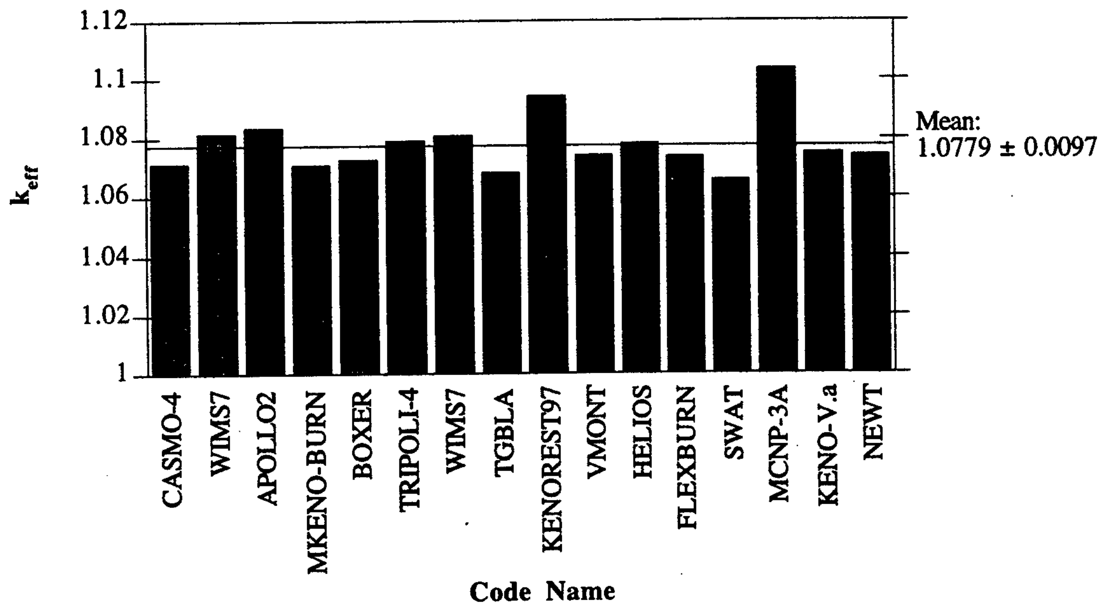

Fig. 2. Results of k_{eff} calculations by international participants in OECD Phase 3B Benchmark

CONCLUSIONS

Although still a developmental prototype, NEWT offers accurate solution of complex problem domains formerly not possible using discrete ordinates methods. As ORNL works both in-house and with beta-testers, it is hoped to develop a fully functional code designed to meet user requirements, as well as a NEWT-based SCALE CSAS sequence, to be released with SCALE-5. NEWT is also being incorporated as a option in a multidimensional depletion sequence (SAS2D), which is currently under development. NEWT is not intended as a replacement for Monte Carlo or other numerical methods; however, it has unique features that will make it the code of choice in select applications where detailed deterministic solutions are needed.

REFERENCES

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2. Y. Naito and H. Okuno, "Nuclide Composition and Neutron Multiplication Factor of BWR Spent Fuel Assembly - OECD/NEA Burnup Credit Criticality Benchmark Phase IIIB," Japan Atomic Energy Research Institute, November 1996.

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