TRANSACTIONS

OF THE
AMERICAN NUCLEAR SOCIETY
AND THE
EUROPEAN NUCLEAR SOCIETY

2007 INTERNATIONAL CONFERENCE
ON
MAKING THE RENAISSANCE REAL

November 11–15, 2007
Omni Shoreham Hotel
Washington, D.C.

Volume 97
TANSAO 97 1–952 (2007)
ISSN: 0003-018X

Jess Gehin (ORNL)
ANS Technical Program Chair

Andre Versteegh (NRG)
ENS Technical Program Chair

Pavel V. Tsvetkov (Texas A&M)
Assistant ANS Technical Program Chair

Julie B. Rule (ANS)
Editor

Ellen M. Leitschuh (ANS)
Coordinator

CASMO-5 ENDF/B-VII R0 Comparison to B&W Criticals Series 1810

Joel Rhodes, Kord Smith, Deokjung Lee, and Zhiwen Xu

Studsvik Scandpower, Inc.
Idaho Falls, ID, 83402
Joel.Rhodes@studsvik.com

INTRODUCTION

A neutron data library based upon the recently released ENDF/B-VII R0 evaluation has been generated for the LWR advanced lattice physics code CASMO-5. This paper details some CASMO-5 comparisons with this new data library for the B&W 1810 series of criticals.

CASMO-5 LATTICE PHYSICS CODE

The CASMO-5 [1] lattice physics code can be used for both BWR and PWR analysis and shares much methods heritage with CASMO-4 [2]:

- Equivalence theorem based resonance calculation.
- 1D collision probability based pincell calculations performed in the library group structure.
- 2D heterogeneous Method of Characteristics based transport calculation (typically performed in 31 groups for UO2 lattices, 50 groups for MOX lattices, and 95 groups for reflector calculations.
- Predictor/corrector based depletion (with optional azimuthal depletion).
- 18 group gamma calculation.
- Automated case matrix generation capability for SIMULATE-3 and SIMULATE-4 [3] library generation.

CASMO-5 also has several advanced numerical models/features not present in CASMO-4:

- Optimum 3 polar angle numerical quadrature (T-Y quadrature). [4]
- Characteristics based Dancoff factor calculation (square geometry with reflective boundary conditions).
- Quadratic Gd-depletion model.
- Enhanced BWR cruciform control rod geometries.

The transition from CASMO-3 to CASMO-4, entailed mainly a change in spatial detail (changing from a 2D transport solution based upon homogeneous pincells to a 2D transport solution with full heterogeneous geometry). Likewise, the transition from CASMO-4 to CASMO-5 also added more spatial detail in the 2D transport solution, but more importantly it added significantly more detail in the energy dimension (from 70 energy groups to 586 energy groups).

CASMO-5 ENDF/B-VII R0 NEUTRON LIBRARY

Because the underlying neutron data library is extremely important to a lattice physics code, the recent (Dec. 2006) release of the ENDF/B-VII R0 (E7R0) evaluation [5] provided an opportunity to generate a neutron data library for CASMO-5 based upon the latest available data.

NJOY99.227 was used to process the ENDF/B-VII R0 data to generate a 586 group library for CASMO-5. This library has 128 fast groups (20 MeV to 9.118 keV), 41 resonance groups with shielded data (9.118 keV to 10 eV), 375 narrow groups (10 eV to 0.625 eV) and 42 thermal groups (below 0.625 eV).

This energy structure allows the U-238 resonance at 6.67 eV, and the Pu-240 resonance at ~1.0 eV, to be explicitly treated and reduce reliance on resonance self-shielding models in this energy range. This neutron data library provides energy condensation capabilities and flexibility in CASMO-5 that has not previously been available in the CASMO code line.

The CASMO-5 E7R0 library has 408 nuclides/materials with shielded data for 61 nuclides including major fission products. Pn-scattering data up to order 5 is present for nuclides where anisotropic scattering effects are important.

B&W CRITICALS (1810 SERIES)

Although comparisons to continuous energy Monte Carlo calculations are often performed for lattice physics code evaluation, experimental criticals provide a more direct method for code evaluation.

One of the most widely analyzed series of criticals is the Babcock & Wilcox (B&W) 1810 Series [6]. These critical experiments represent realistic reactor configurations and consist of a 5x5 array of either 15x15 PWR or 16x16 PWR assemblies. The central “assembly” was modified from one experiment to the next. Some cores contained gadolinium fuel pins, Ag-In-Cd (AIC), B4C control rods, or hollow rods. All core configurations from this set were analyzed, with the exception of Core 11, which was explicitly designed to measure resonance parameters.

The geometry of Cores 1 through 17 was representative of Babcock & Wilcox, Westinghouse type reactors. These cores consisted of a 5x5 array of pseudo-assemblies (individual pins without spacers), each containing a 15x15 pin array. Cores 1 through 10 consisted of a uniform fuel enrichment distribution. Cores 12 through 17 consisted of a high enrichment central area surrounded by a low enriched zone (split zone enrichments).

The geometry of Cores 18 through 20 was representative of a Combustion Engineering type of reactor design. These cores consisted of a 5x5 array of pseudo-assemblies, each containing a 16x16 pin array. All of these cores contained a high enrichment central area surrounded by a low enriched zone. These cores differed only in the number of gadolinium fuel pins present.

RESULTS

Table I presents the critical eigenvalues for the B&W 1810 series of criticals from the CASMO-5 2D transport solution run with a P0 scattering order and in 95 groups.

Table I. CASMO-5 E7R0 Critical Eigenvalue

	Boron (PPM)	# 4% Gd Pins	# of AIC Rods	CASMO-5 K-eff
01	1337.9	--	--	1.00136
02	1250.0	--	16	1.00092
03	1239.3	20	--	1.00098
04	1171.7	20	16	1.00171
05	1208.0	28	--	1.00068
05A	1191.3	32	--	1.00058
05B	1207.1	28	--	1.00076
06	1155.8	28	16	1.00095
06A	1135.6	32	16	1.00095
07	1208.8	28	--	1.00064
08	1170.7	36	--	1.00083
09	1130.5	36	16	1.00079
10	1177.1	36	16	1.00061
12	1899.3	--	--	1.00105
13	1635.4	--	16	1.00157
14	1653.8	28	16	1.00080
15	1479.7	28	16	1.00146
16	1579.4	36	---	1.00084
17	1432.1	36	16	1.00106
18	1776.8	--	--	1.00232
19	1628.3	16	--	1.00203
20	1499.0	32	--	1.00195
Average (Cores 01-17)				1.00098
Stand. Dev. (Cores 01-17)				**0.00033**
Average (Cores 18-20)				1.00210
Stand. Dev. (Cores 18-20)				**0.00019**
Average (All Cores)				1.00113
Stand. Dev (All Cores)				**0.00050**

The CASMO calculations were run with the default MoC quadrature (128 azimuthal angles, 3 polar angles, and a ray-spacing of 0.05 cm), but with 5 coolant rings instead of the standard 3 coolant rings in order to better model the steep flux gradients at cold conditions. The 95 group energy structure is the standard CASMO group structure typically used for reflector calculations with additional high energy groups in order to more accurately capture high energy leakage effects.

The CASMO P0 transport cross section is calculated using the inscatter approximation with a P1-flux calculated from a fission source in hydrogen.

CONCLUSIONS

Comparisons of CASMO-5 calculations performed with the ENDF/B-VII R0 data library to the B&W 1810 series of critical experiments demonstrates excellent agreement with no obvious bias versus the number of Gd pins, number of AIC rods, or boron concentration. This comparison helps underscore the accuracy of the CASMO-5 code and the E7R0 library. Although Pn effects were not included in this comparison, the P0 transport cross section appears to perform quite well.

Comprehensive benchmarking of CASMO-5 with the ENDF/B-VII R0 library versus reactor models and continuous energy Monte Carlo depletion calculations has also been performed[7]. This E7R0 library is still extremely new at this time and improved results should be obtained as its performance is further quantified.

REFERENCES

1. J. RHODES, K. SMITH, "CASMO-5 Development and Applications," *Advances in Nuclear Analysis and Simulation* , PHYSOR-2006, Vancouver, B.C. Sept. (2006).

2. K. SMITH, J. RHODES, "CASMO-4 Characteristics Methods for Two-dimensional PWR and BWR Core Calculations," *Trans. Am. Nucl. Soc.* **83**, 322, Washington D.C., Nov. (2000).

3. T. BAHADIR, S.O. LINDAHL, and S. PALMTAG, "SIMULATE-4 Multigroup Nodal Code with Microscopic Depletion Model." *Mathematics and Computation, Supercomputing, Reactor Physics and Nuclear and Biological Applications*, Avignon France, Sept. (2005).

4. A. YAMAMOTO, M. TABUCHI, N. SUGIMURA, T. USHIO and M. MORI, "Derivation of Optimum Polar Angle Quadrature Set for the Method of Characteristics Based on Approximation Error for the Bickley Function," *J. Nucl. Sci. Technol.*, Vol 44, Feb. (2007).

5. M.B. CHADWICK, P. OBLOZINSKY, M. HERMAN et al.,"ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology", *Nuclear Data Sheets*, Vol. 107, pp. 2931-3060, (2006).

6. L. W. LEWMAN, “Urania-Gadolinia: Nuclear Model Development and Critical Experiment Benchmark,” DOE/ET/34212-41, Babcock & Wilcox (1984).

7. Z. XU, J. RHODES, K. SMITH, and N. GHEORGHIU,”MCNP-5/ORIGEN 2.2/MCODE-2.2 versus CASMO-5 Depletion for a Heavily Gd-Poisoned BWR Fuel Assembly,” *Trans. Am. Nucl. Soc.*, **96**, 575, Boston (2007).