

Computational Physics and Engineering Division

**Development and Testing of a New AMPX Cross Section Processing
System for Criticality Safety Applications**

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The AMPX code system has been limited to processing Version 5 formats of the Evaluated Nuclear Data File (ENDF). Work is in progress to upgrade the AMPX code system to process ENDF/B-VI data. A substantial amount of code development is complete, and the latest version of AMPX has the capability to: (I.) process cross sections in the resolved resonance region (RRR) using the multi-pole formalism, and (II.) produce continuous energy cross sections from ENDF/B-VI data. Comprehensive testing of the new modules is underway, and the purpose of this work is to establish the capabilities of the new AMPX code system for criticality safety applications.

I. Multi-pole Processing

The multi-pole method was developed at Argonne National Laboratory (ANL) as a rigorous and equivalent alternative for processing resolved resonance data that is expressed in the Reich-Moore formalism.¹ KRYSTAL is a new AMPX module that reads the ENDF resonance information, generates multi-pole parameters from the Reich-Moore data and stores the “pole”

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parameters in an AMPX master library. NITAWL-II is the current SCALE module that generates resonance self-shielded cross sections in the RRR using the Nordheim Integral Treatment.² Since NITAWL-II cannot process multi-pole data, a replacement module (i.e., NITAWL-III) has been developed to process the “pole” parameters.

In an effort to test NITAWL-III and the corresponding multi-pole method for criticality safety applications, several critical experiments that are documented in Reference 3 were calculated. Reference 3 identified problems for low-enriched thermal homogeneous systems with low H/U ratios (i.e., $H/U < 8$) using the 199-group VITAMIN-B6 library in SCALE. The 199-group library has Bondarenko shielding factors over the entire energy range for all nuclides. As a result, problem dependent cross sections are generated using the narrow resonance (NR) approximation throughout the resonance region. Low enriched uranium systems with low H/U values are strongly influenced by the ^{238}U resonances that are wide relative to the scattering width. Consequently, the NR approximation for these systems is inadequate.

Multi-pole parameters were generated for ^{238}U , and the revised multigroup cross sections for ^{238}U were implemented in the 199-group library. Four low-enriched homogeneous uranium criticals (i.e., “Green Block” experiments) from Reference 3 were calculated using CSAS25 with NITAWL-III and the revised 199-group library. The results are presented in Column (d) of Table I. Using the original 199-group library, calculations are presented for comparison in Column (c) of Table I.A. Results are also presented in Table I.A for the 238-group ENDF/B-V library using CSAS25 with NITAWL-II and NITAWL-III (i.e., Columns (a) and (b), respectively).

Based on the 238-group results, the calculated k_{eff} values obtained with NITAWL-III self-shielded cross sections are within two standard deviations of the results obtained with NITAWL-II. The good agreement demonstrates that the capabilities of NITAWL-II are maintained in the latest version of NITAWL. The poor results obtained with the unmodified VITAMIN-B6 library are attributed to the NR resonance approximation and are consistent with the results presented in Reference 3.

The multi-pole parameters for ^{238}U lead to a significant improvement in the calculated multiplication factor. With the NR approximation, the mean calculated k_{eff} for Cases 82 through 85 is 1.0277, and the maximum k_{eff} is 1.0382 ± 0.0016 . By using the multi-pole parameters for ^{238}U , the mean calculated system multiplication factor for these 4 experiments is 1.0124 with a maximum system multiplication factor of 1.0222 ± 0.0016 . As a result, using the Nordheim Integral treatment with the ^{238}U multi-pole data leads to a 1.5% decrease in system multiplication relative to the NR approximation.

II. Continuous Energy Cross Section Processing

Several new modules were developed to process continuous energy cross sections from ENDF/B-VI data. For example, the module POLIDENT was upgraded to process ENDF/B-VI data and generate continuous energy cross section values.⁴ In an effort to test the new AMPX modules, continuous energy cross sections based on ENDF/B-VI data were generated for CENTRM, the new continuous energy resolved resonance processing module.

The work presented in Reference 5 examined the International OECD/NEA Criticality Working Group Benchmark 20 problem using CENTRM processed ENDF/B-V cross sections.

The cases evaluate UO_2 fuel pellets partially dissolved in borated solution. Due to the presence of resonance absorbers in more than one spatial zone, NITAWL cannot treat the resolved resonances accurately for self-shielding calculations. CENTRM is needed to explicitly calculate a problem dependent point flux for generating self-shielded cross sections.

Using ENDF/B-VI cross sections, each case was analyzed using the code sequence BONAMI, CENTRM/PMC, and XSDRNPM. For comparison, the cases were analyzed using the same code sequence, except NITAWL-II was used to process the resolved resonances. The cases were also modeled with MCNP⁶ using ENDF/B-VI data. The calculated results are presented in Table I.B. The mean calculated k_4 for the MCNP and CENTRM cases is 1.0281 and 1.0309, respectively. In contrast, the mean calculated k_4 for the NITAWL cases is 1.0163. Additionally, looking at the results on a case-by-case basis, even larger, positive and negative deviations of the NITAWL results from the reference MCNP results are observed. CENTRM provides a significant improvement over NITAWL for processing resolved resonances in problems with resonance absorbers in more than one spatial zone.

For the cases in Table I.B, MCNP point cross sections were also generated using the new AMPX code system coupled with NJOY. The cases were calculated using MCNP with the AMPX/NJOY generated cross sections, and the results are presented in Column (d) of Table I.B. The mean calculated k_4 for the results in Column (d) is 1.0340. The AMPX/NJOY generated cross sections for MCNP are within 1% of the results obtained with CENTRM and MCNP (i.e., Column (c)). Currently, efforts are underway to investigate the differences between the MCNP cross sections generated by AMPX/NJOY and the cross sections provided with MCNP.

A new AMPX code system exists that can process ENDF/B-VI data. The results obtained with the multi-pole formalism and continuous energy CENTRM cross sections in the resolved resonance region demonstrate the capability of AMPX to accurately process ENDF/B-VI cross sections for criticality safety applications.

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Table I: Calculated Results for Testing the New AMPX Code System

I.A: CSAS25 Results for Testing NITAWL-III and 199-group VITAMIN-B6 Library With ²³⁸U Multi-pole Data.

ID	Homogenized Uranium in Paraffin Cases			$k_{eff} \pm \delta$				Δk			
	Wt % ²³⁵ U	H/X	Refl.	238-group (NITAWL-II) (a)	238-group (NITAWL-III) (b)	199-group (BONAMI) (c)	199-group ²³⁸ U-multi-pole parameters (NITAWL-III) (d)	(b-a)	(c-b)	(d-b)	(d-c)
82	2.0	293.9	Bare	1.0038 ± 0.0016	1.0000 ± 0.0016	1.0227 ± 0.0016	1.0083 ± 0.0016	-0.0038	0.0227	0.0083	-0.0144
83	2.0	406.3	Plex.	1.0026 ± 0.0015	1.0009 ± 0.0015	1.0175 ± 0.0014	1.0023 ± 0.0015	-0.0017	0.0166	0.0014	-0.0152
84	3.0	133.4	Plex.	1.0082 ± 0.0018	1.0056 ± 0.0017	1.0324 ± 0.0018	1.0166 ± 0.0021	-0.0026	0.0268	0.0110	-0.0158
85	3.0	133.4	Bare	1.0147 ± 0.0018	1.0125 ± 0.0017	1.0382 ± 0.0016	1.0222 ± 0.0016	-0.0022	0.0257	0.0097	-0.0160