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Release of the ENDF/B-VII.1 Evaluated Nuclear Data File

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DISCLAIMER

Release of the ENDF/B-VII.1 Evaluated Nuclear Data File

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INTRODUCTION

The Cross Section Evaluation Working Group (CSEWG) released the ENDF/B-VII.1 library on December 22, 2011. The ENDF/B-VII.1 library is CSEWG's latest recommended evaluated nuclear data file for use in nuclear science and technology applications, and incorporates advances made in the five years since the release of ENDF/B-VII.0, including: many new evaluation in the neutron sublibrary (423 in all and over 190 of these contain covariances), new fission product yields and a greatly improved decay data sublibrary.

In this summary, I will highlight some of the changes. The full list of major changes includes:

- Many more evaluations in the neutron sublibrary (ENDF/B-VII.0 contained 393 isotopes, ENDF/B-VII.1 contains 423);
- Extensive nuclear reaction data on uncertainties (covariance data evaluations) for 190 isotopes;
- All minor actinide cross section evaluations improved, including new U, Np, Pu and Am evaluations and the use of the JENDL-4 library for Cm, Bk, Cf, Es, Fm and others;
- Structural material evaluations have been advanced through use of recent resolved and unresolved resonance analyses of new measured data;
- New light nucleus R-matrix evaluations have been developed for the nuclides ^{3}He, ^{9}Be, and ^{6}Li.
- Modifications to thermal neutron reactions on fission products (isotopes of Mo, Tc, Rh, Ag, Cs, Nd, Sm, Eu) and neutron absorber materials (Cd, Gd);
- Fission energy release evaluations;
- Fission product yield advances for fission-spectrum neutrons and 14 MeV neutrons incident on ^{239}Pu, including details of the neutron energy dependence over the fast neutron range from 0.5 - 2.0 MeV; and
- A new decay data sublibrary.

All of these are detailed in Ref. [1] and the rest of the December 2011 issue of Nuclear Data Sheets.

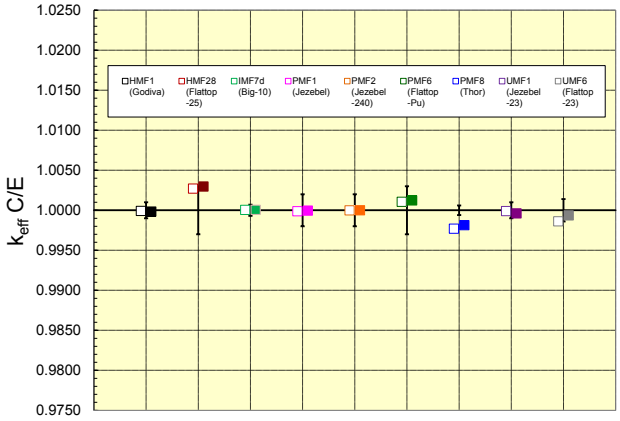

Fig. 1. ICSBEP benchmarks from Los Alamos's FAST suite, demonstrating the continuing excellent agreement of ENDF/B-VII.1 with integral experiments.

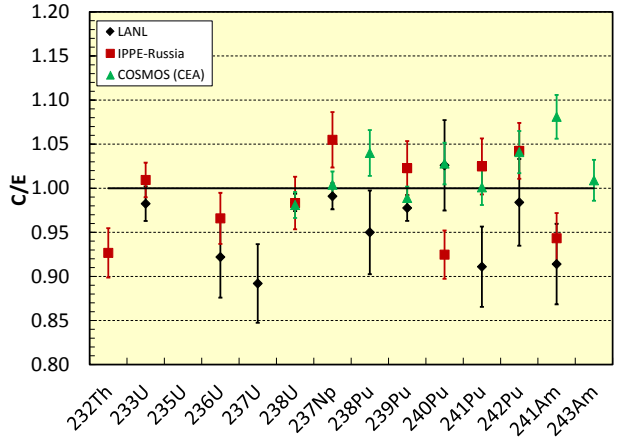

Fig. 2. Fission reaction spectral index C/E values for selected actinides from LANL (Flattop-25), PROFIL and FUND-IPPE-FR-MULT-RRR-001 assemblies. The spectral index ratio is usually made to ^{235}U(n,f), but some of the LANL ratios are to ^{239}Pu(n,f).

The ENDF/B-VII.1 library is the most extensively tested ENDF release and many new benchmark tests were added since the release of ENDF/B-VII.0 (see Ref

[2]). Although the library has undergone substantial revision since ENDF/B-VII.0, we have preserved the excellent agreement with key benchmarks as one can see in the selection of FAST critical assembly simulations from Los Alamos National Laboratory in Fig. 1. In Fig. 2 we show some results from new benchmark tests, namely spectral index measurements. In this type of test, one irradiates a small sample of a material and then radiochemically assays it after irradiation. This allows one to target specific reactions in a material for testing. As one can see in Fig. 2, we have overall good agreement at the 2 sigma level.

In the remainder of this summary, I will focus on changes that directly impact reactor simulations, namely: improvements to Zr (as Zr is used in reactor cladding), the new decay library (as it determines decay heat) and the expanded suite of data covariance. Finally, I will present some thoughts on the future of the ENDF library.

LIBRARY HIGHLIGHTS

Sample of new evaluations: Zirconium isotopes

Zr is used in fuel rod cladding due to its corrosion-resistance and low thermal neutron absorption cross section. These properties also make it an attractive material for advanced reactor design either as a moderator in the form of zirconium hydride or an inert matrix fuel material. The ENDF/B-VI.8 evaluations from the 1970's relied on fits to experimental data and lacked double differential outgoing particle distributions and gamma production data. These evaluations were replaced in the ENDF/B-VII.0 library with complete, but theory based, evaluations. Testing by KAPL and Bettis demonstrated a drop in reactivity in various proprietary benchmarks in the transition from ENDF/B-VI.8 to ENDF/B-VII.0. Sensitivity studies revealed that these deficiencies can be remedied by adjusting the elastic cross section as was done in ENDF/B-VI.8 (see Fig. 3).

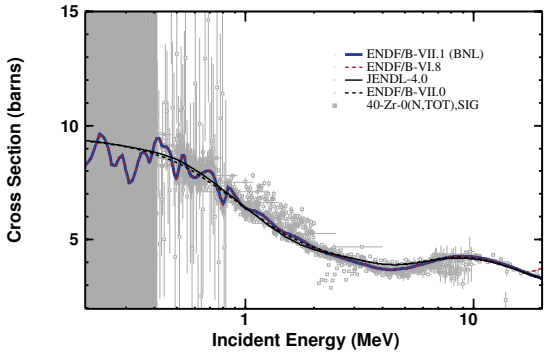

Fig. 3. The ^{nat}Zr total cross section. In the ENDF/B-VII.1 evaluations, (n,el) cross sections were adjusted so that the (n,tot) cross section matches experimental data and the legacy ENDF/B-VI.8 evaluation.

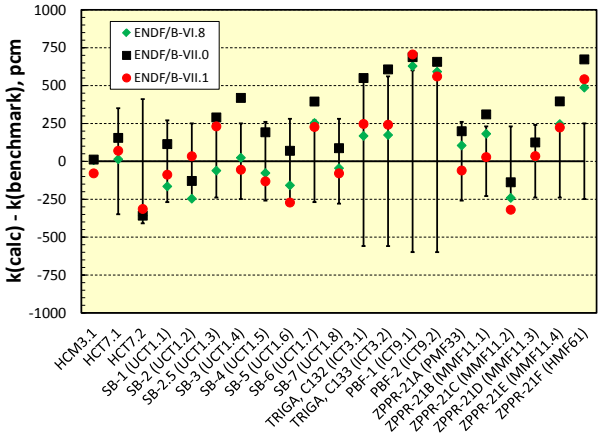

Fig. 4. ICSBEP benchmarks containing significant amounts of Zr either in the form of control rods or reflectors. The new ENDF/B-VII.1 evaluations demonstrate a substantial improvement over older releases, especially in TRIGA and ZPPR benchmarks.

The new ENDF/B-VII.1 evaluations detailed in Ref. [1] contain several improvements, including new resonance regions for ^{90,91}Zr, new fast evaluations created using a new dispersive soft-rotor optical model potential and covariance data from the COMMARA-2.0 project. The (n,el) cross sections in the Zr evaluations were tuned to match (n,tot) data in the fast region, enabling the new evaluations to capture the best features of the ENDF/B-VII.0 and ENDF/B-VI.8 evaluations. In Fig. 4, we show benchmark simulation results for a variety of critical assemblies which contain significant amounts of Zr, either in the form of control rods or reflectors. One can clearly see the improvement in the ZPPR and TRIGA benchmarks (Ref. [2]).

Decay sublibrary

The new ENDF/B-VII.1 decay sublibrary is a substantial improvement over the previous ENDF/B-VII.0 release. The new sublibrary consists of 3817 materials, each one corresponding to the ground state, a long-lived state or an isomer of a nucleus. 19 poorly known materials in ENDF/B-VII.0 were dropped. This sublibrary is based mainly on the decay data in the Evaluated Nuclear Structure Data File (ENSDF), with some crucial additions: incomplete data were supplemented using the Nuclear Wallet Cards (2011), Q-values were computed from the Audi-Wapstra 2003 mass tables and atomic data was taken from Lawrence Livermore National Laboratory's Evaluated Atomic Data Library [1]. The sublibrary was improved further with beta-decay modeling using the Cascading Gamma Multiplicity (CGM) model and by comparing to Total Absorption Gamma-ray Spectroscopy (TAGS) data. In Ref. [1], it is noted that the TAGS comparison is directly responsible for the excellent agreement with experiment shown in Fig. 5.

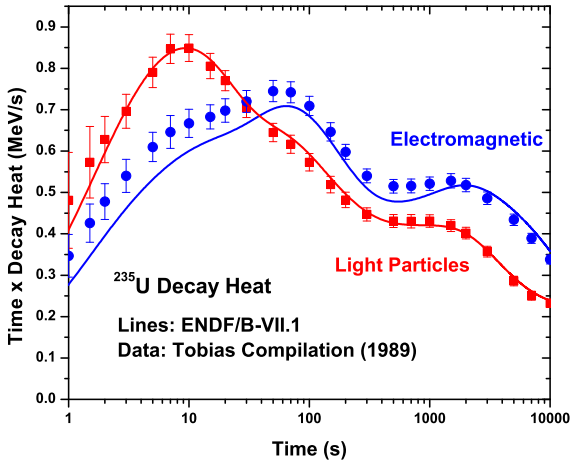

Fig. 5. Decay heat times the time for a single neutron induced fission event on ^{235}U at thermal neutron energies, broken out into electromagnetic and light particle components.

Covariance data

The ENDF/B-VII.1 library contains over 190 neutron evaluations with covariances, more than any previous ENDF library. A summary of these covariances is provided in Table I. Notable is the substantial increase of covariance data for structural materials and minor actinides (see Ref. [4]). Although the mean values of all quantities in the major actinides were unchanged, covariances for Prompt Fission Neutron Spectrum (PFNS) were added (see Ref. [5]). Sample plots of these covariances are shown in Figs. 6 and 7.

Table I. Summary of neutron cross section covariance data sets in ENDF/B-VII.1.

Category	Materials	Comment
Light nuclei	12	6 evaluated by R-matrix; 6 low fidelity estimates
Structural + FP	105	38 evaluated for COMMARA-2.0; 40 updated low fidelity estimates; 15 for criticality safety programs; 12 for other purposes
Priority Actinides	20	13 evaluated for COMMARA-2.0; 1 from ENDF/B-VII.0; 6 from JENDL-4.0
Minor Actinides	53	All from JENDL-4.0

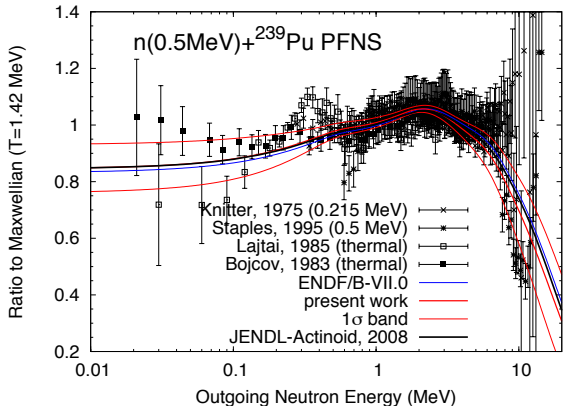

Fig. 6. ^{239}Pu Prompt Fission Neutron Spectrum (PFNS) for 0.5 MeV incident neutrons, in ratio to a Maxwellian spectrum. The mean value of the PFNS in ENDF/B-VII.1 is the same as ENDF/B-VII.0, but the covariance data is new.

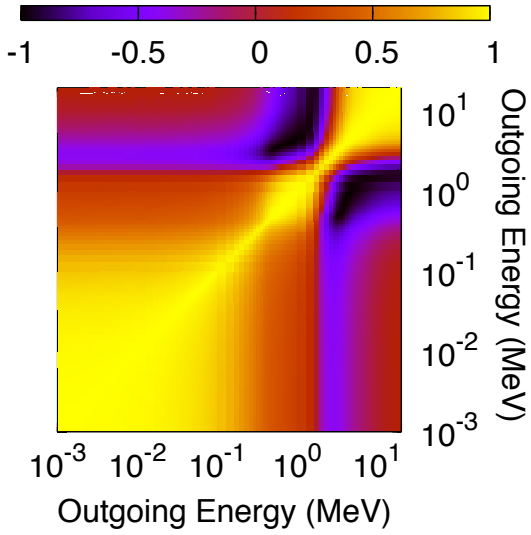

Fig. 7. The newly evaluated covariance for ^{239}Pu PFNS for 0.5 MeV incident neutrons.

RESULTS

This summary barely touches on the five years' worth of advances present in the ENDF/B-VII.1 library. We expect that these changes will lead to improved integral performance in reactors and other applications. Furthermore, the expansion of covariance data in this release will allow for better uncertainty quantification, reducing design margins and costs.

The ENDF library is an ongoing and evolving effort. Currently, the ENDF data community embarking on several parallel efforts to improve library management:

- The adoption of a continuous integration system to provide evaluators "instant" feedback on the quality of

their evaluations and to provide data users with working "beta" quality libraries in between major releases.

- The transition to new hierarchical data format: the Generalized Nuclear Data (GND) format. We expect GND to enable new kinds of evaluated data which cannot be accommodated in the legacy ENDF format.
- The development of data assimilation and uncertainty propagation techniques to enable the consistent use of integral experimental data in the evaluation process.

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