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# Comparison of ENDF/B-VIII.0 and ENDF/B-VII.1 libraries with MCS code.

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## 1. Introduction

Recently, ENDF/B-VIII.0 library was released by Cross Section Evaluation Working Group (CSEWG). The ENDF library is used to calculate Monte Carlo codes. It is important to verify the cross-section library before performing Monte Carlo calculations.

This paper presents comparison of ENDF/B-VIII.0 library and the ENDF/B-VII.1 library using ICSBEP model, VERA benchmark, PMR model. This process is important for ensuring the reliability of the ENDF/B-VIII.0 library. MCS code was used to compare ENDF/B-VIII.0 library and ENDF/B-VII.1 library. Some of ICSBEP model, VERA benchmark model and PMR model were used for the calculation. The ENDF/B-VIII.0 library was generated using NJOY code.

## 2. Verification of ENDF/B-VIII.0 library

This section describes the newly released ENDF/B-VIII.0 and the MCS and NJOY codes used in this study. Also, the ICSBEP benchmark model used in calculation was described.

### *2.1 ENDF/B-VIII.0 library*

ENDF/B-VIII.0 was released in early 2018, incorporating work from the US national and international nuclear science communities. This library has been published in the form of the ENDF/B-VI.0 format and a new generalized nuclear database structure. Unlike ENDF/B-VII.1, ENDF/B-VIII.0 had significant changes in the neutron response to major actinides and other nuclides that affect the simulation of nuclear criticality. The isotope $^{1}$H, $^{16}$O, $^{56}$Fe, $^{235,238}$U, $^{239}$Pu reflected results of ENDF/B-VIII.0 in Collaborative International Evaluation Library Organization (CIELO). Neutron standards and thermal scattering libraries are included in ENDF/B-VIII.0. In the Table I, the neutron sublibrary has expanded 32% to contain 557 evaluations (see Table I.) [1].

Table I. Number of Nuclides Provided Each ENDF/B Library in Each Sublibrary [1].

| Sublibrary | VIII.0 | VII.1 | VII.0 | VI.8 |
|---|---|---|---|---|
| Neutron | 557 | 423 | 393 | 328 |
| Thermal n-scattering | 33 | 21 | 20 | 15 |
| Proton | 49 | 48 | 48 | 35 |
| Deuteron | 5 | 5 | 5 | 2 |
| Triton | 5 | 3 | 3 | 1 |
| Helium3 | 3 | 2 | 2 | 1 |
| Alpha | 1 | n/a | n/a | n/a |
| Photonuclear | 163 | 163 | 163 | n/a |

### *2.2 MCS code*

MCS code has been developed for the purpose of large scale reactor analysis with accelerated Monte Carlo simulation. MCS uses continuous energy cross-section libraries and detailed geometrical data to estimate neutronics design parameters of a nuclear reactor such as effective multiplication factor, neutron flux, and fission power [2].

### *2.3 NJOY code*

NJOY code is a comprehensive computer code package for calculating continuous energy cross-section, multi-group cross-section from evaluated nuclear data. NJOY code generates libraries for variety of particle transport and analysis codes, using files evaluated for neutrons, photons, and charged particles [3].

### *2.4 Specification of the ICSBEP model*

Some of the International Criticality Safety Benchmark Experimental Problem (ICSBEP) was selected for verification of each library. ICSBEP is one of the criticality benchmark. Figure 1 shows assembly of LMT007 case1, one of the various models used in the calculations. Figure 2 shows vertical cross-section view of rod. The specification of LMT007 case1 model are described in Table II.

Table II. Specification of LMT007 case1 model

| Parameter | Value |
|---|---|
| Fuel rod diameter. (cm) | 0.7729 |
| Fuel rod length. (cm) | 30 |
| Fuel density. (g/cm$^3$) | 18.974 |
| Bottom reflector. (cm) | 21.59 |
| Moderator density. (g/cm$^3$) | 0.997771 |
| Pin pitch (cm) | 1.30 |
| Number of rods | 394 |
| Total height (cm) | 60.49 |
| Top reflector height (cm) | 8.90 |

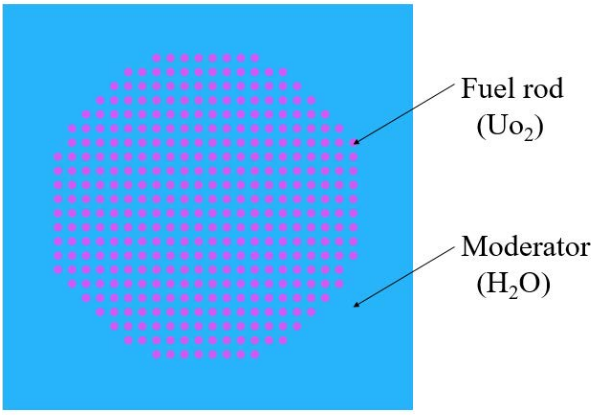


Fig 1. LMT007 case1 assembly design

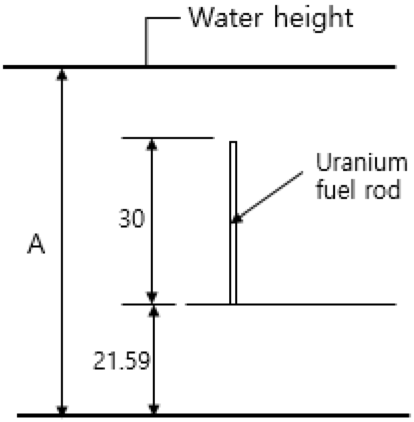


Fig 2. Vertical cross-sectional view of rod configuration with infinite radial water reflector. [4]

### 3. Numerical Results

Table III-X shows results of the ICSBEP model. The model used for calculation was selected from some of the ICSBEP model. The multiplication factor($k_{eff}$) values of Table III-X shows that ENDF/B-VIII.0 values is less than ENDF/B-VII.1 value substantially. The deviations of the $k_{eff}$ values are about 20 pcm. Table III-X shows the result of comparing ENDF/B-VIII.0 and ENDF/B-VII.1 using MCS code. In Table III-X, 500 inactive cycles and 2000 active cycles were used with a neutron history of 10000 per cycle. The temperature was assumed to be 300K.

In order to compare ENDF/B-VIII.0 library and ENDF/B-VII.1 library, other models were selected. Selected models are VERA benchmark model and PMR model. A material of fuel and cladding in VERA benchmark is uranium and zirconium. Table XI shows $k_{eff}$ value of 2D pin-cell calculation. The deviations of the $k_{eff}$ values are about 20 pcm. In Table XI, 20 inactive cycles and 100 active cycles were used with a neutron history of 50000 per cycle. The temperature was assumed to be 600K. Unlike the other models, the fuel type of PMR model is TRISO particle. Table XII shows $k_{eff}$ value of PMR model. The deviations of the $k_{eff}$ values are about 26 pcm. In Table XII, 20 inactive cycles and 100 active cycles were used with a neutron history of 50000 per cycle. The temperature was assumed to be 900K.

Table III. $k_{eff}$ Results in LCT 001 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 1.00030 | 1.00075 | -45 |
| Case02 | 0.99972 | 1.00019 | -47 |
| Case03 | 0.99903 | 0.99971 | -60 |
| Case04 | 0.99944 | 1.00004 | -60 |
| Case05 | 0.99764 | 0.99831 | -67 |
| Case06 | 0.99960 | 1.00009 | -49 |
| Case07 | 0.99906 | 0.99938 | -32 |
| Case08 | 0.99790 | 0.99838 | -48 |

Table IV. $k_{eff}$ Results in LCT 008 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 1.00124 | 1.00245 | -121 |
| Case02 | 1.00182 | 1.00273 | -91 |
| Case03 | 1.00234 | 1.00300 | -66 |
| Case04 | 1.00141 | 1.00212 | -71 |
| Case05 | 1.00122 | 1.00200 | -78 |
| Case06 | 1.00117 | 1.00223 | -106 |
| Case07 | 1.00072 | 1.00141 | -69 |
| Case08 | 1.00018 | 1.00084 | -66 |
| Case09 | 1.00004 | 1.00141 | -137 |
| Case10 | 1.00119 | 1.00229 | -110 |
| Case11 | 1.00224 | 1.00286 | -62 |
| Case12 | 1.00140 | 1.00224 | -84 |
| Case13 | 1.00140 | 1.00224 | -84 |
| Case14 | 1.00192 | 1.00225 | -33 |
| Case15 | 1.00125 | 1.00206 | -81 |
| Case16 | 1.00149 | 1.00241 | -91 |
| Case17 | 1.00032 | 1.00124 | -92 |

Table V. $k_{eff}$ Results in LCT 017 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 1.00194 | 1.00267 | -73 |
| Case02 | 1.00158 | 1.00258 | -100 |
| Case03 | 1.00058 | 1.00114 | -56 |
| Case04 | 0.99855 | 0.99960 | -105 |
| Case05 | 0.99987 | 1.00098 | -111 |
| Case06 | 1.00041 | 1.00065 | -24 |
| Case07 | 1.00040 | 1.00125 | -85 |
| Case08 | 0.99922 | 0.99963 | -41 |
| Case09 | 0.99840 | 0.99878 | -38 |
| Case10 | 0.99878 | 0.99912 | -34 |
| Case11 | 0.99899 | 0.99937 | -38 |
| Case12 | 0.99891 | 0.99979 | -88 |
| Case13 | 0.99951 | 0.99995 | -44 |

| | | | |
|---|---|---|---|
| Case14 | 0.99981 | 1.00056 | -75 |
| Case15 | 0.99796 | 0.99818 | -22 |
| Case16 | 0.99906 | 0.99942 | -36 |
| Case17 | 1.00031 | 1.00117 | -86 |
| Case18 | 0.99900 | 0.99996 | -96 |
| Case19 | 0.99958 | 1.00016 | -58 |
| Case20 | 0.99858 | 0.99916 | -58 |
| Case21 | 0.99849 | 0.99967 | -118 |
| Case22 | 0.99781 | 0.99882 | -101 |
| Case23 | 1.00012 | 1.00095 | -83 |
| Case24 | 1.00099 | 1.00131 | -32 |
| Case25 | 0.99893 | 0.99972 | -79 |
| Case26 | 0.99637 | 0.99744 | -107 |
| Case27 | 0.99807 | 0.99969 | -162 |
| Case28 | 0.99966 | 0.99998 | -32 |
| Case29 | 0.99959 | 1.00114 | -155 |

Table VI. $k_{eff}$ Results in LCT 039 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 0.99701 | 0.99825 | -124 |
| Case02 | 0.99619 | 0.99707 | -88 |
| Case03 | 0.99518 | 0.99680 | -162 |
| Case04 | 0.99548 | 0.99700 | -152 |
| Case05 | 0.99697 | 0.99758 | -61 |
| Case06 | 0.99490 | 0.99560 | -70 |
| Case07 | 0.99503 | 0.99607 | -104 |
| Case08 | 0.99491 | 0.99609 | -118 |
| Case09 | 0.99441 | 0.99528 | -87 |
| Case10 | 0.99437 | 0.99545 | -108 |
| Case11 | 0.99464 | 0.99576 | -112 |
| Case12 | 0.99438 | 0.99555 | -117 |
| Case13 | 0.99408 | 0.99563 | -155 |
| Case14 | 0.99467 | 0.99586 | -119 |
| Case15 | 0.99488 | 0.99586 | -98 |
| Case16 | 0.99515 | 0.99657 | -142 |
| Case17 | 0.99467 | 0.99577 | -110 |

Table VII. $k_{eff}$ Results in LCT 050 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 0.99921 | 1.00078 | -157 |
| Case02 | 0.99915 | 1.00027 | -112 |
| Case03 | 0.99977 | 1.00095 | -118 |
| Case04 | 0.99935 | 1.00065 | -130 |
| Case05 | 1.00065 | 1.00191 | -126 |
| Case06 | 1.00045 | 1.00214 | -169 |
| Case07 | 1.00542 | 1.00655 | -113 |
| Case08 | 0.99776 | 0.99904 | -128 |

Table VIII. $k_{eff}$ Results in LCT 054 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 1.00247 | 1.00346 | 99 |
| Case02 | 1.00250 | 1.00295 | 45 |
| Case03 | 1.00239 | 1.00314 | 75 |
| Case04 | 1.00253 | 1.00356 | 103 |
| Case05 | 1.00202 | 1.00310 | 108 |
| Case06 | 1.00208 | 1.00269 | 61 |
| Case07 | 1.00228 | 1.00268 | 40 |
| Case08 | 1.00189 | 1.00258 | 69 |

Table IX. $k_{eff}$ Results in LCT 065 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case 02 | 1.00329 | 1.00508 | -179 |
| Case03 | 1.00242 | 1.00434 | -192 |
| Case04 | 1.00240 | 1.00496 | -256 |
| Case05 | 1.00327 | 1.00499 | -172 |
| Case06 | 1.00376 | 1.00505 | -129 |
| Case07 | 0.97706 | 0.97796 | -90 |
| Case08 | 1.00372 | 1.00486 | -114 |
| Case09 | 1.00281 | 1.00455 | -174 |
| Case10 | 1.00245 | 1.00368 | -123 |
| Case11 | 1.00273 | 1.00354 | -81 |
| Case12 | 1.00237 | 1.00369 | -132 |
| Case13 | 1.00199 | 1.00295 | -96 |
| Case14 | 1.00335 | 1.00430 | -95 |
| Case15 | 1.00300 | 1.00382 | -82 |
| Case16 | 1.00256 | 1.00381 | -125 |
| Case17 | 1.00227 | 1.00365 | -138 |

Table X. $k_{eff}$ Results in LCT 090 Model

| Model name | ENDF/B-VIII.0 (A) | ENDF/B-VII.1 (B) | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| Case01 | 1.00251 | 1.00280 | -29 |
| Case02 | 1.00225 | 1.00305 | -80 |
| Case03 | 1.00239 | 1.00273 | -34 |
| Case04 | 1.00297 | 1.00373 | -76 |
| Case05 | 1.00245 | 1.00368 | -123 |
| Case06 | 1.00263 | 1.00323 | -60 |
| Case07 | 1.00193 | 1.00306 | -113 |
| Case08 | 1.00211 | 1.00315 | -104 |
| Case09 | 1.00243 | 1.00288 | -45 |

Table XI. VERA Benchmark Model $k_{eff}$

| Model name | ENDF/B-VIII.0 | ENDF/B-VII.1 | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| VERA Benchmark | 1.18380 | 1.18307 | -73 |

Table XII. PMR Model $k_{eff}$

| Model name | ENDF/B-VIII.0 | ENDF/B-VII.1 | Diff (A)-(B) (pcm) |
|---|---|---|---|
| | $k_{eff}$ | $k_{eff}$ | |
| PMR Compact | 1.25005 | 1.24817 | 118 |

### 4. Conclusions

This paper presents comparison of ENDF/B-VIII.0 library and the ENDF/B-VII.1 library using ICSBEP model, VERA benchmark, PMR model.

Numerically, in the ICSBEP and VERA benchmark models, ENDF/B-VIII.0 showed lower $k_{eff}$ value than ENDF/B-VII.1. The difference of two results is within statistical error. However, the results of PMR model showed that $k_{eff}$ value was higher ENDF/B-VIII.0 than ENDF/B-VII.1.

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