Validation of Recently Available and Newly Evaluated Nuclear Data Files for Tungsten

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1. Introduction

Tungsten (W) is considered as a prime candidate for plasma facing materials in the ITER project and other fusion-related development projects. For W isotopes, the neutron-induced nuclear reaction cross sections from the ENDF/B-VI.8 were adopted for the FENDL-2.1 [1] and ENDF/B-VII.0 and those from the JENDL-3.3 were adopted for the JEFF-3.1. However the cross sections from the existing nuclear data files failed to reproduce the recent measured data and resulted in large discrepancies in the neutron/gamma-ray leakage spectra from the W shielding and the k_{eff} values for the fast critical assemblies with W. [2]

Recently, some attempts have been made to improve the evaluated nuclear data files for W isotopes. Trkov et al. of Jozef Stefan Institute (JSI), Slovenia produced new evaluations for the W isotopes (W-180, -182, -183, -184, and -186) in the neutron energy range up to 150 MeV including the covariance information under the auspices of the IAEA. [3] Nuclear data team of KAERI also produced new evaluations for W-182, -183, -184, and -186, which showed significant improvements of the individual reaction cross sections and the neutron emission spectra induced by incident neutrons in the fast energy range. [2]

In this study, the recently available and newly evaluated nuclear data files have been validated through some fusion shielding and criticality safety benchmark problems. The MCNPX code was used along with the ACE-format libraries processed by the patched version of the NJOY99.161 code.

2. Benchmark Problem

Two fusion shielding benchmarks were taken from the SINBAD [4]. The OKTAVIAN-W benchmark is a pulsed sphere experiment for an intense 14 MeV neutron transmission performed at the D-T neutron source facility of Osaka University. Neutron and gamma-ray leakage spectra from the W sphere of 40 cm-diameter were measured by the time-of-flight (TOF) technique. The FNS-W benchmark experiment was conducted at the Fusion Neutronics Source (FNS) facility of the JAEA. The neutron and gamma-ray leakage spectra from a W cylinder assembly of 62.9 cm-diameter and 50.7 cm-height were measured at three different positions (7.6 cm, 22.8 cm, and 38.0 cm) for the D-T neutron source.

The criticality safety benchmark problems containing W were selected from the ICSBEP handbook [5]. Table I shows a list of the benchmark problems. These benchmarks are subdivided into four categories according to the main fissionable isotopes: 12 HEU, 2 IEU, 1 Pu, and 2 U-233 benchmarks. The W-to-major fissile ratios inform us of the impacts of W data on the k_{eff} estimations for the benchmarks.

Table I: Brief Description of the Criticality Safety Benchmark Problems

Main fissionable isotope	Benchmark series identifier	Assembly description	W-to-major fissile ratio
HEU	heumf-060	ZPR-9/4	5.87
	heumf-067	ZPR-9/5	4.73
	heumf-067	ZPR-9/6	4.74
	heumf-070	ZPR-9/7	4.69
	heumf-070	ZPR-9/8	4.74
	heumf-070	ZPR-9/9	4.73
	heumf-085	Case 6	4.83
	heumf-003	Case 8	4.48
	heumf-003	Case 9	9.98
	heumf-003	Case 10	24.73
	heumf-003	Case 11	55.10
	heucm-003		0.18
IEU	ieumf-014	ZPR-9/2	2.72
	ieumf-014	ZPR-9/3	4.76
PU	pumf-005		8.57
U-233	u233mf-004	Case 1	2.47
	u233mf-004	Case 2	11.45

3. Calculation Results

The benchmark calculations were performed with the MCNPX-2.5.0 and compared with the measurements. Reference calculation was carried out with the library based on the ENDF/B-VII.0. In order to investigate the impacts of the W data on the benchmark calculations, the W data were replaced by recently available and newly evaluated cross sections of W isotopes in the reference calculation.

3.1 Shielding Benchmark

The neutron leakage spectra from the OKTAVIAN-W sphere are given in Fig. 1. The ENDF/B-VII.0 showed an underestimation of the fast neutrons above 7 MeV when compared to the measurements. The results by the JEFF-3.1 showed a slight overestimation of the neutrons below 0.4 MeV and an underestimation of the neutrons above 0.7 MeV when compared to the measurements. For the new evaluations of the IAEA and KAERI, the leakage neutrons above 6 MeV still showed large discrepancies with regard to the measurements, but slight improvements were observed in its shape for the existing libraries.

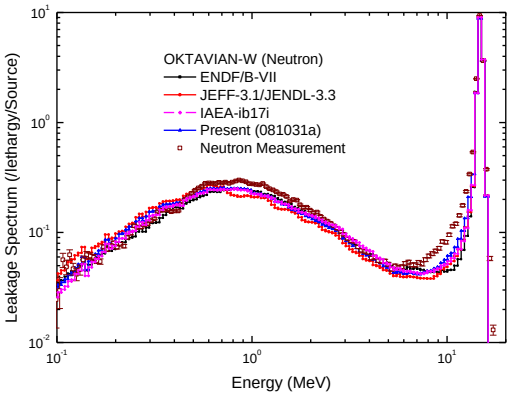

Fig. 1. Neutron leakage spectrum from the OKTAVIAN-W sphere.

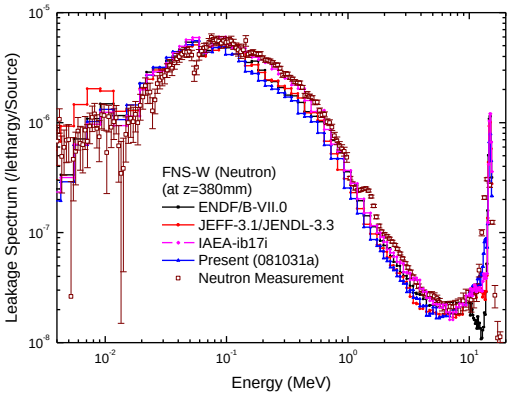

Fig. 2. Neutron leakage spectrum at 38.0 cm for the FNS-W benchmark.

For the FNS-W benchmark, the neutron leakage spectra measured at the position of 38.0 cm were compared with the calculation results in Fig. 2. For the ENDF/B-VII.0, outstanding depressions of the leakage neutrons are observed at around 10 to 13 MeV. The small drops of the leakage neutrons also appeared at around 13 MeV for the JEFF-3.1 and IAEA data. These may be mainly attributed to the bad choices of the neutron emission spectra for the existing nuclear data libraries. On the other hand, the new evaluation of KAERI showed a remarkable progress at around 10 MeV when compared to the other libraries. The results with the IAEA data are considerably improved in the energy range above 60 keV showing better agreements with the measurements. The gamma-ray leakage spectra calculated with the new evaluations tend to seriously underestimate the measurements all over the energy ranges.

3.2 Criticality Safety Benchmark

As shown in Fig. 3, the ENDF/B-VII.0 results generally agree well with the measured k_{eff}'s within about 2%. However, the JEFF-3.1 has a tendency to increase the k_{eff}'s up to about 3% for a few ZPR-9 fast critical assemblies. For the new evaluations, considerable improvements were made, showing better agreements with the measured k_{eff}'s within about 1%. The new evaluation of KAERI has a tendency to estimate the k_{eff}'s in a nearly constant difference with the ENDF/B-VII.0 results.

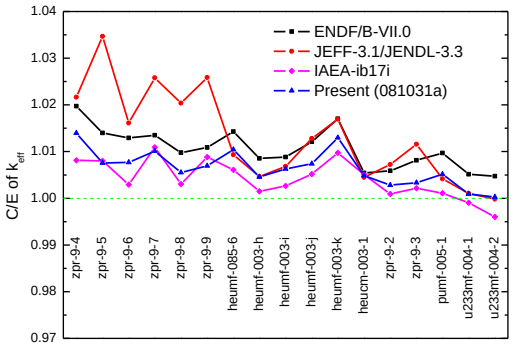

Fig. 3. Calculated-to-experimental (C/E) ratios of k_{eff}'s for the criticality safety benchmarks with W isotopes.

4. Summary

The validations of the recently available and newly evaluated nuclear data files of the W isotopes have been performed for 2 shielding benchmarks and 17 criticality safety benchmarks. For the new evaluations of the IAEA and KAERI, considerable improvements were achieved in the neutron leakage spectra calculation for the FNS-W benchmark and the criticality estimations.

ACKNOWLEDGEMENTS

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