Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2026

Validation of the ACE-Format Neutron Library Generation System for the D1S Code Using Shutdown Dose Rate Calculations

Do Heon Kim*, Young-Sik Cho
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Korea
Corresponding author: kimdh@kaeri.re.kr

***Keywords: D1S neutron library, D1S method, SDDR, FENDL-3.1d, EAF-2007, D1SUNED**

1. Introduction

In recent years, the D1S method has been increasingly used as an alternative to the R2S method for accurately performing activation analyses of complex large-scale radiation facilities. KAERI is developing a D1S-based activation analysis system to perform shutdown dose rate (SDDR) calculations for complex fusion facilities. This system consists of an ACE-format neutron library generation system for the D1S code and an MCNP6[1]-based D1S activation analysis code.

Currently, the D1SUNED code[2] is used for activation analyses of ITER, and its embedded D1S neutron library was produced based on FENDL-3.1d[3] and EAF-2007[4] nuclear data. In this study, to validate the developed D1S library generation system, a D1S library was generated using the same nuclear data files as those used in D1SUNED. SDDR calculations were performed for major structural material nuclides, such as Cr, Mn, Fe, Co, Ni, and Ta, and the results were compared with those obtained using the embedded D1SUNED library. The D1SUNED-3.1.2 code was used to perform the SDDR calculations.

2. D1S Activation Analysis System

The D1S activation analysis system established in this study consists of three components, as shown in Fig. 1: an ACE library generation system for D1S codes, a time correction factor calculation program to account for neutron irradiation and cooling scenarios, and an MCNP6-based D1S code.

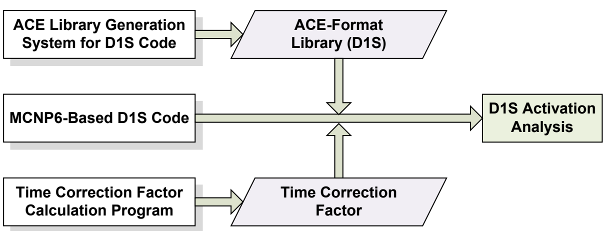

Fig. 1. Overview of the D1S activation analysis system.

As illustrated in Fig. 2, neutron activation cross section files, decay data files, and ACE-format libraries for MCNP are used as inputs for the generation of the D1S library. The D1S library generation program produces a D1S library by replacing the neutron reaction cross sections and prompt gamma-ray data in the given ACE files with neutron activation cross sections and decay gamma-ray data. This approach differs from that of D1SUNED, which modifies the ENDF files themselves to include neutron activation cross sections and decay gamma-ray data, and then processes them with the NJOY code[5] to produce an ACE-format library for the D1S code.

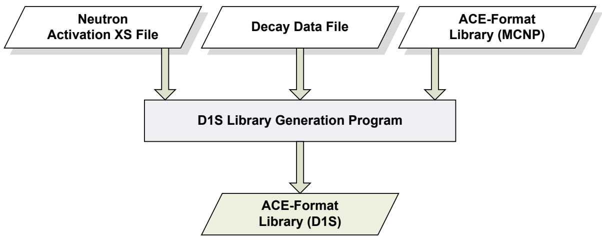

Fig. 2. Overview of the ACE library generation system for the D1S code.

The D1SKNN31d library produced in this study using FENDL-3.1d and EAF-2007 contains 81 nuclides, which is a significant increase compared to the 68 nuclides included in the embedded library (D1SDATA) of D1SUNED version 3.1.2.

3. Shutdown Dose Rate Calculations

A validation problem was established to validate the D1S library on a nuclide-by-nuclide basis. As shown in Fig. 3, it has the same geometry as Test Problem #1 among the test problems included in the D1SUNED code, and Cells 2 and 3 are filled with the target nuclides for validation in their natural isotopic compositions.

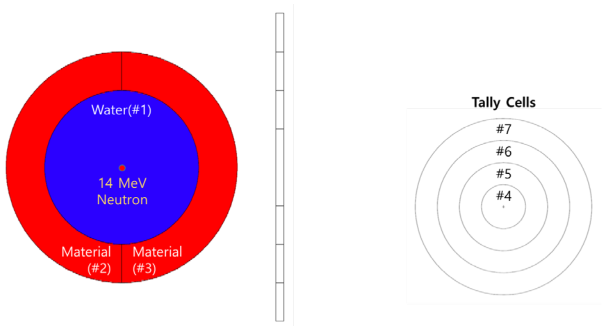

Fig. 3. Geometry and tally cell of the D1S library validation problem.

First, validation calculations of the D1SKNN31d library were performed for major structural material nuclides that have a relatively significant impact on SDDR, namely Cr, Mn, Fe, Co, Ni, and Ta. From these calculations, the SDDR in the tally cells, the dose contribution from the parent nuclides, the dose contribution from daughter nuclides, and the dose contribution from each geometric cell were obtained after cooling times of 1 day and 12 days. The results were then compared with those obtained using the D1SDATA library.

Figures 4 to 9 show the SDDR calculation results in the tally cells for Cr, Mn, Fe, Co, Ni, and Ta, respectively. Overall, the two libraries show almost identical calculation results. Although relative errors exceeding 1% are observed in some cases with very small SDDR values, these discrepancies can be resolved by increasing the Monte Carlo simulation time.

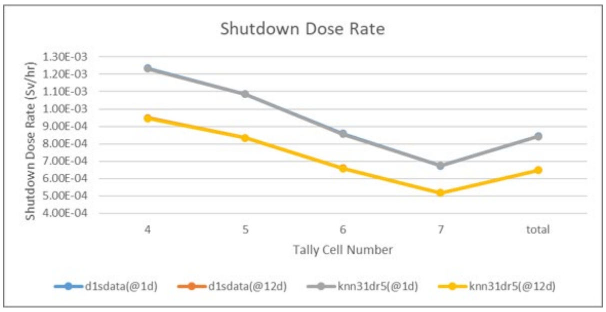

Fig. 4. SDDR validation results in the tally cells for the Cr D1S library.

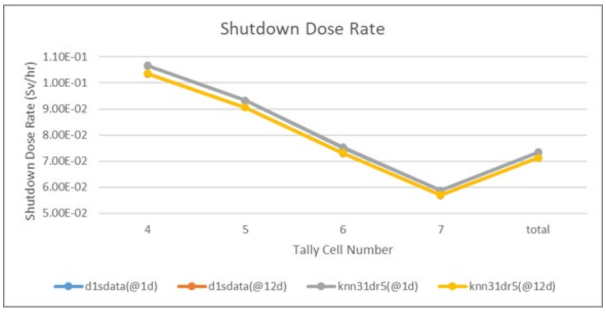

Fig. 5. SDDR validation results in the tally cells for the Mn D1S library.

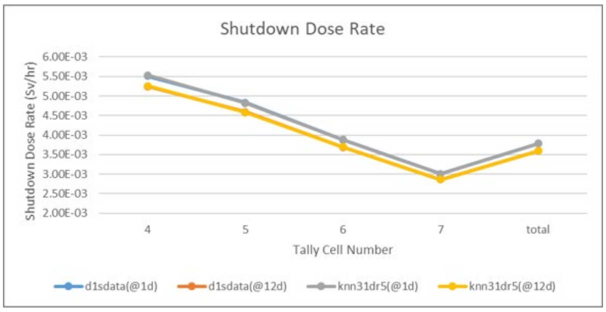

Fig. 6. SDDR validation results in the tally cells for the Fe D1S library.

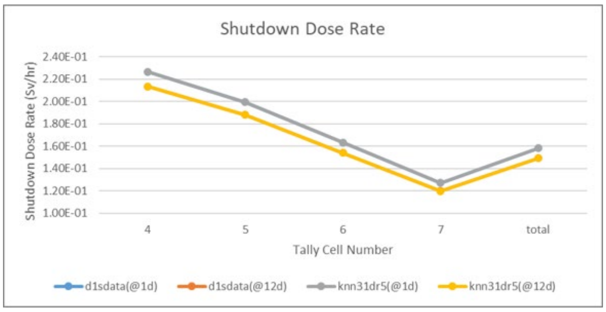

Fig. 7. SDDR validation results in the tally cells for the Co D1S library.

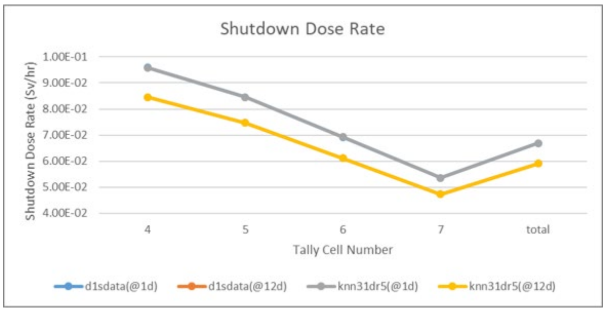

Fig. 8. SDDR validation results in the tally cells for the Ni D1S library.

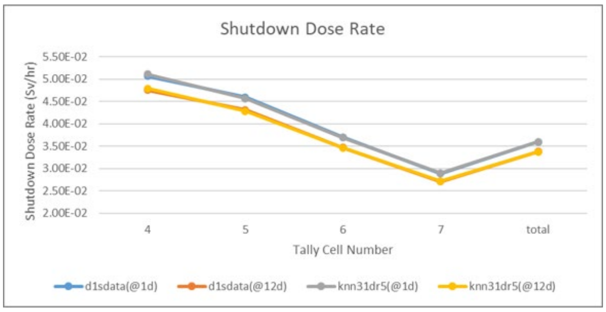

Fig. 9. SDDR validation results in the tally cells for the Ta D1S library.

4. Summary

In this study, an ACE-format neutron library generation system for the D1S code was developed and validated using SDDR calculations. The D1SKNN31d library was generated using FENDL-3.1d and EAF-2007 nuclear data and was designed to be compatible with the MCNP-based D1S activation analysis system.

To verify the reliability of the developed library generation system, nuclide-by-nuclide validation calculations were performed for major structural material nuclides, including Cr, Mn, Fe, Co, Ni, and Ta, using a validation problem based on the D1SUNED Test Problem #1 geometry. The calculated SDDR values and dose contributions from parent and daughter nuclides were compared with those obtained using the embedded D1SUNED (D1SDATA) library.

The comparison results demonstrated that the D1SKNN31d library produces nearly identical SDDR results to those obtained with the D1SUNED embedded library. Minor discrepancies observed in very low

SDDR values were attributed to statistical uncertainties in the Monte Carlo simulations and can be reduced by increasing the simulation time.

These results confirm the validity and reliability of the developed ACE-format neutron library generation system for D1S-based SDDR analyses. The developed system can therefore serve as an independent and flexible platform for activation analysis of complex fusion facilities.

ACKNOWLEDGMENTS

The work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea Government (Ministry of Science and ICT) (No. RS-2024-00443333) and the KAERI Institutional Program (Project No. 524530-26).

REFERENCES

[1] C.J. Werner, Ed., "MCNP User's Manual Code Version 6.2," LA-UR-17-29981, Los Alamos National Laboratory, 2017.
[2] P. Sauvan, et al., "D1SUNED System for the Determination of Decay Photon Related Quantities," Fusion Engineering and Design, vol. 151, no. 111399 (2020).
[3] G. Schnabel, et al., "FENDL: A Library for Fusion Research and Applications," Nuclear Data Sheets, vol. 193, p. 1 (2024).
[4] R.A. Forrest, J. Kopecky, and J.-Ch. Sublet, "The European Activation File: EAF-2007 Neutron-Induced Cross Section Library," UKAEA FUS 535, UKAEA, 2007.
[5] A.C. Kahler, Ed., "The NJOY Nuclear Data Processing System, Version 2016," LA-UR-17-20093, Los Alamos National Laboratory, 2018.