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Benchmark study of TRIPOLI-4® for decommissioning purposes

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This paper presents a verification benchmark of the TRIPOLI-4®/DARWIN-PEPIN2 sequence for performing radiological characterization of reactors in decommissioning phase. Computed activities were compared with measured activities included in the JPDR experimental program. A good agreement was found with a variability of about $\mp 30\%$. The current benchmark exercise successfully validates the general computational procedure.

KEYWORDS: *activation analysis, TRIPOLI-4®, DARWIN*

Introduction

Decommissioning of nuclear facilities is nowadays one of the most important issues in the field of nuclear technology. Radiological characterization is essential in planning of a decommissioning project. It ensures the decommissioning activities to be conducted in safe and rational manners. However, before using software for specific applications, one should try to repeat some benchmarks and analyze their results. The JPDR (Japan Power Demonstration Reactor) benchmark [1,2] was used to validate the TRIPOLI-4®/DARWIN-PEPIN2 [3, 4] sequence for performing neutron activation calculations. Calculated fluxes and activities were compared properly with experimental data and uncertainties associated with these parameters were obtained.

Materials and Methods

The JPDR configuration and the irradiation history were modeled according to data reported in [1, 2]. Monte Carlo based neutron transport calculations were performed with TRIPOLI-4® (v4.10) [3] and EPDL-97 data library in order to determine the neutron fluence rates in different material regions. The neutron fluence rates were calculated at the nominal power rating conditions and each flux was homogenized in 315 energy groups. To speed-up the simulation in the radial direction a variance reduction adjustment was applied [5]. The neutron fluence rates obtained in the structures of interest were then used to model the decay chains of different nuclides with DARWIN-PEPIN2 package (v2.4) [4]. The nuclear data library used for activation was JEFF-3.1/A.

Results

Figure 1 shows the radial broad group profiles obtained from the unbiased simulation. Group 1 (G1) represents fast neutrons above 0.1 MeV, Group 3 (G3) is the thermal group with energies below 0.4 eV and Group 2 (G2) covers all energies between these limits. This profile behaves qualitatively as expected and illustrates the quite rapid change in neutron spectrum that occurs at various locations through the excore regions.

In table 1 are reported neutron flux obtained in the bioshield with the reference and the biased simulations. Results show that the biased simulation induced no error in the flux determination and improve the simulation efficiency ε defined as $\varepsilon = 1/\sigma^2 \times t$ with σ the Monte Carlo uncertainty and t the computation time.

The biased simulation was then used to estimate the flux in various structures of interest. The results were then injected as input data in the DARWIN package to estimate the activity levels. The evolution of ⁶⁰Co activity with the radial distance in the reactor vessel is reported in figure 2. The ratio of the calculated to experimental (C/E) value is also reported and varies between 0.88 and 1.27. C/E values obtained axially in the shroud and the cladding are reported in table 2 and vary between 0.777 and 1.32.

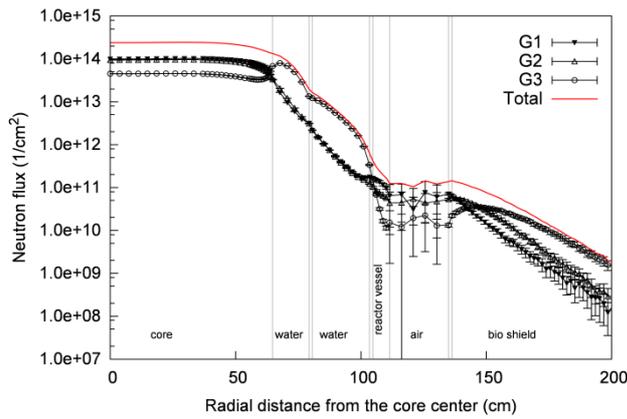


Figure 1: TRIPOLI-4® three group radial flux profiles at mid core plane

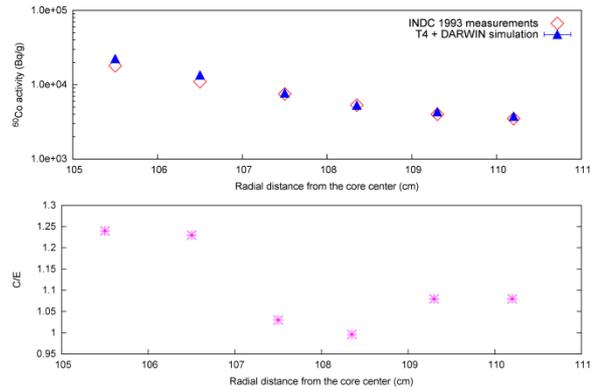


Figure 2: In up panel, measured (red open squares) and simulated (blue triangles) activity values obtained at h=360 cm are compared. The behavior of the C/E value is reported in down panel.

	Batches nb. (5000 n/batch)	t (s)	Flux (n/s/cm2)	σ (%)	ϵ
REF	100 000	1 058 058	6.99E+10	20.42	2.27E-05
IC	19 500	929 453	6.97E+10	2.17	2.07E-03

Table 1: Validation and figure of merit of the biased scheme.

	C/E values in the shroud	C/E values in the cladding
Axial distance from core center	0 cm	241
⁵⁵ Fe	0.978	0.811
⁶⁰ Co	1.20	1.11
⁶³ Ni	1.32	0.777

Table 2: C/E values for activity determined in the shroud.

Conclusion

C/E values show good agreement with experiment to within $\pm 30\%$. The current benchmark exercise successfully validates the general computational procedure, as well as the use of TRIPOLI-4® variance reduction techniques for decommissioning purposes.

References

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