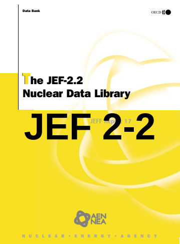

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Benchmark of JEF2 actinides and fission products with isotopic depletion in French power reactor Gravelines.

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1)Introduction

This paper describes a part of a work done at CEA concerning fuel burnup. The objective was to check the capabilities of JEF2 and Apollo2 code to predict concentrations of various isotopes at different burnup up 60 000 MWd/t.

2) Nuclear data and methods

We used a multigroup library with 172 groups based on JEF2.2, except for the fission yields which are taken from Meek and Rider 1981 compilation. For the fission yields, the differences between JEF2 and the former are small except for some fission products with low yields.

The code Apollo2 permits the accurate self-shielding calculation in the real geometry and can model heavy slowing-down in each energy region like wide and narrow resonance. The flux calculation is done using the collision probability interface current formalism. Isotopic depletion equations were solved using the standard predictor-corrector algorithm of the Apollo2 code in order to insure good spectrum calculation at any time. The isotopic chain is composed of 103 isotopes including 83 fission products with a pseudo-fission product for each main fissile isotopes.

Simulation of the irradiation history of the pin analysed is simplified to follow the important features of the real history. Changes in local power due to the cooling within a cycle or between cycles, changes in fuel and moderator temperatures and boron concentration are taken into account. only. For each sample, the end of the irradiation is determined by adjusting the local power to reach the experimental value of isotopic concentration ratio Nd148/U238.

4)Typical uncertainties in analysis

We made rough estimates of calculation uncertainties to appreciate the calculation to experimental value ratio (C/E). This includes temperature errors, Nd148 fission yields uncertainties mainly those U235 and Pu239, self-shielding model error for U238 which is estimated to be below 1%. Error analysis are still studied and therefore so these are only the first estimations.

Isotopes	Cycle 2	Cycle 3	Cycle 4	Cycle 5
$^{235}U/^{238}U$	0,7	0,8	2,75	3,0
$^{238}U/^{239}Pu$	1,0	1,0	1,4	1,5
$^{238}Pu/^{239}Pu$	1,9	1,9	1,9	3,3
$^{240}Pu/^{239}Pu$	0,7	0,7	1,0	1,0
$^{241}Pu/^{239}Pu$	0,9	0,8	0,5	0,4
$^{242}Pu/^{239}Pu$	1,8	1,7	2,0	2,1

Table 1 Uncertainties in % for Uranium and Plutonium

5)Mains results

We will only give the average C/E for majors actinides, minors actinides and fission products. Wherever a trend of a C/E with burnup appears, we mark it with a question mark.

5-1)Actinides

The U236/U238 ratio show a systematic shift of the mean value.

Isotopes	^{234}U/^{238}U (%)	^{235}U/^{238}U (%)	^{236}U/^{238}U (%)
mean value and dispersion	+2,9±1,9	+5,3±4,1(?)	-4,3±0,8

Table 2 Results for Uranium

For the Pu239 and Pu240, the C/E are within the uncertainties but there is a systematic shift of the mean value which is believed to be significant. Concerning the Pu241 and Pu242 the disagreements are greater and significant. For the Plutonium isotopes, experimental uncertainties are negligible.

isotopes	^{238}U/^{239}Pu (%)	^{238}Pu/^{239}Pu (%)	^{240}Pu/^{239}Pu (%)	^{241}Pu/^{239}Pu (%)	^{242}Pu/^{239}Pu (%)
mean value and dispersion	-2,7±1,2	-5,6±3,8	-2,6±1,7	-3,2±1,6	-8,9±3,6

Table 3 Results for Plutonium

isotopes	^{241}Am/^{238}U (%)	^{242m}Am/^{241}Am (%)	^{243}Am/^{241}Am (%)
mean value and dispersion	-1,9±6,2	-18,6±15,5	-1,7±16,3

Table 4 Results for Americium

isotopes	^{243}Cm/^{244}Cm (%)	^{245}Cm/^{244}Cm (%)	^{246}Cm/^{244}Cm (%)	^{247}Cm/^{244}Cm (%)
mean value and dispersion	-10,2±10,3	2,6±2	-24,7±16	-89,1±8,8

Table 5 Results for Curium

5-2)Fission products

Concerning Neodymium and Caesium isotopes, agreement with experiment seems to be rather good. But we have not estimated the calculation errors at that time. The most important disagreements are found for Eu154/Cs135 and Ce144/Cs135.

Isotopes	^{145}Nd/^{238}U (%)	^{143}Nd/^{145}Nd (%)	^{144}Nd/^{145}Nd (%)	^{146}Nd/^{145}Nd (%)	^{148}Nd/^{145}Nd (%)	^{150}Nd/^{145}Nd (%)
mean values and dispersion	-0,6±0,4	3,3±1,4	-2,6±0,8	0,3±0,3	0,8±0,4	1,4±0,6

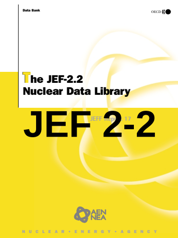
Tableau 6 Results for Neodymium

Isotopes	^{135}Cs/^{238}U (%)	^{133}Cs/^{135}Cs (%)	^{134}Cs/^{135}Cs (%)	^{137}Cs/^{135}Cs (%)
mean values and dispersion	-2,8±1,9	-1,4±2,6	-5,5±5,5	-4,4±2,7

Table 7 Caesium

Isotopes	^{134}Cs/^{137}Cs (%)	^{154}Eu/^{137}Cs (%)	^{106}Ru/^{137}Cs (%)	^{144}Ce/^{137}Cs (%)
mean values and dispersion	-0,18±4	76,9±22,4(?)	-0,3±6,4	17,7±9,5

Table 8 Others fission products measured by γ spectrometry



6)Preliminary qualitative trends about nuclear data

We are at early stage to get quantitative trends on nuclear data. We also can not exclude the errors in calculation so we must take care about these preliminary conclusions. Some sensitivities of isotopic ratio to average cross-section are being calculated to obtain some quantitative trends. Unfortunately, we can the moment give only the qualitative trends.

The U235 capture cross-section seems too low. There is no evidence of significant problem with the U238 capture cross-section. For the Plutonium isotopes, there is a systematic negative shift on mean values. This indicate perhaps a slight problem on cross-sections.
The most evident disagreement among Americium isotopes concerns Am242 metastable isotope but as the dispersion is very important it is difficult to conclude.
For Curium isotopes, the greatest disagreement between experiment and calculation concerns Cm247/Cm244 which reaches -90% with relatively low dispersion which is of the order of magnitude of experimental uncertainty.

Concerning the fission products, we noticed a great disagreement for Eu154. The C/E values for Eu154/Cs137 show a clear trend with burnup. This may be due probably to a too high capture cross-section of Eu153 and/or to a too great build-up of mother isotopes.