HTR-N

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Sensitivity analysis and estimation of major impact of nuclear data uncertainties to reactivity & mass balance

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Sensitivity analysis and estimation of major impact of nuclear data uncertainties to reactivity & mass balance

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1 Introduction

This draft presents microscopic cross-section sensitivity studies and uncertainty calculations on the GTMHR reactivity.

The geometry used is taken from the "GTMHR, Conceptual Design Description Report" [1]. Calculations are performed on a standard assembly : 14 compacts with burnable poison, 202 fuel compacts with PuO_2 fuel (the fuel kernel diameter is 200 µm surrounded by inner PyC, SiC, outer PyC coatings).
Two kinds of fuel are studied : a RG-Pu and a WG-Pu.
The plutonium isotopic vector, in weight percentage are :

	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241
RG-Pu	2.70	54.50	22.9	11.70	7.0	1.20
WG-Pu	0.01	94.0	5.4	0.6	0.01	0.01

The calculation scheme used is taken from DEN/DM2S/SERMA and was developed by X. RAEPSAET and F. DAMIAN [2]. Calculations are performed with the deterministic 2D-transport code APOLLO2 [3]. The flux is calculated by the collision probability method (Pij method). The interface current method is used to calculate each assembly. Self shielding is calculated for plutonium isotopes and for Am-241. A multigroup library (CEA-93-V6) based on JEF-2.2 evaluation is used (172 energy groups – XMAS).

2 Sensitivity calculations at 0 MWday/kg

These calculations are based on the first order perturbation theory. Sensitivity coefficients are calculated for multiplicity, capture and fission.

2.1 RG-Pu fuel :

The geometry is modelled with 1200 kg of plutonium in the reactor and 50 g of Erbium in the fuel assembly.

k_∞(0 MWdays/kg) = 1.13202

Table 1: Sensitivity coefficients for RG-Pu fuel 0 MWdays/kg

Δk/k (pcm/%)	CAPTURE	FISSION	DIFFUSION	NU
Pu-239	-257.9	368.3	0.0	792.4
Pu-240	-191.5	2.1	0.1	3.2
Pu-241	-31.8	106.8	0.0	201.7
Pu-242	-27.8	0.4	0.0	0.6
Am-241	-15.4	0.2	0.0	0.4
Graphite	-5.3		317.6	

Δk/k (pcm/%)	Er-166	Er-167
CAPTURE	-1.5	-33.0

2.2 WG-Pu fuel :

The geometry is modelled with 701 kg of plutonium in the reactor and 441 g of Erbium in the fuel assembly.

k_∞(0 MWdays/kg) = 1.19934

Table 2: Sensitivity coefficients for WG-Pu fuel 0 MWdays/kg

Δk/k (pcm/%)	CAPTURE	FISSION	DIFFUSION	NU
Pu-239	-313.4	467.3	0.1	992.3
Pu-240	-77.8	0.3	0.1	0.5
Pu-241	-1.2	3.7	0.0	7.2
Pu-242	0.0	0.0	0.0	0.0
Am-241	-0.1	0.0	0.0	0.0
Graphite	-6.3		344.6	

Δk/k (pcm/%)	ER166	ER167
CAPTURE	-8.9	-109.3

3 Sensitivity calculations at 650 MWdays/kg

A direct method is used for these calculations : a first reference is performed and the cross section is increased by 1% (in every group) for each isotope and reaction. An overview over the sensitivity coefficients for capture and fission for both RG and WG Pu at zero and 650 MWd/kg HM burn-up is shown in Fig.3.

Table 3: Sensitivity coefficients for RG-Pu fuel 650 MWdays/kg

	Reference	$\sigma_{capt.}$ (Pu-239)	$\sigma_{capt.}$ (Pu-240)	$\sigma_{fiss.}$ (Pu-239)	$\sigma_{fiss.}$ (Pu-241)	$\sigma_{diff.}$ (Graph.)
k_∞	1.01711	1.01589	1.01870	1.01805	1.02001	1.01685
Δk/k (pcm)	-	-120	156	141	285	-26

Table 4: Sensitivity coefficients for WG-Pu fuel 650 MWdays/kg

	Reference	σ capt. (Pu-239)	σ capt. (Pu-240)	σ fiss. (Pu-239)	σ fiss. (Pu-241)	σ diff. (Graph.)
k_∞	1.14682	1.14387	1.14765	1.14985	1.14925	1.14662
Δk/k (pcm)	-	-257	72	264	212	-14

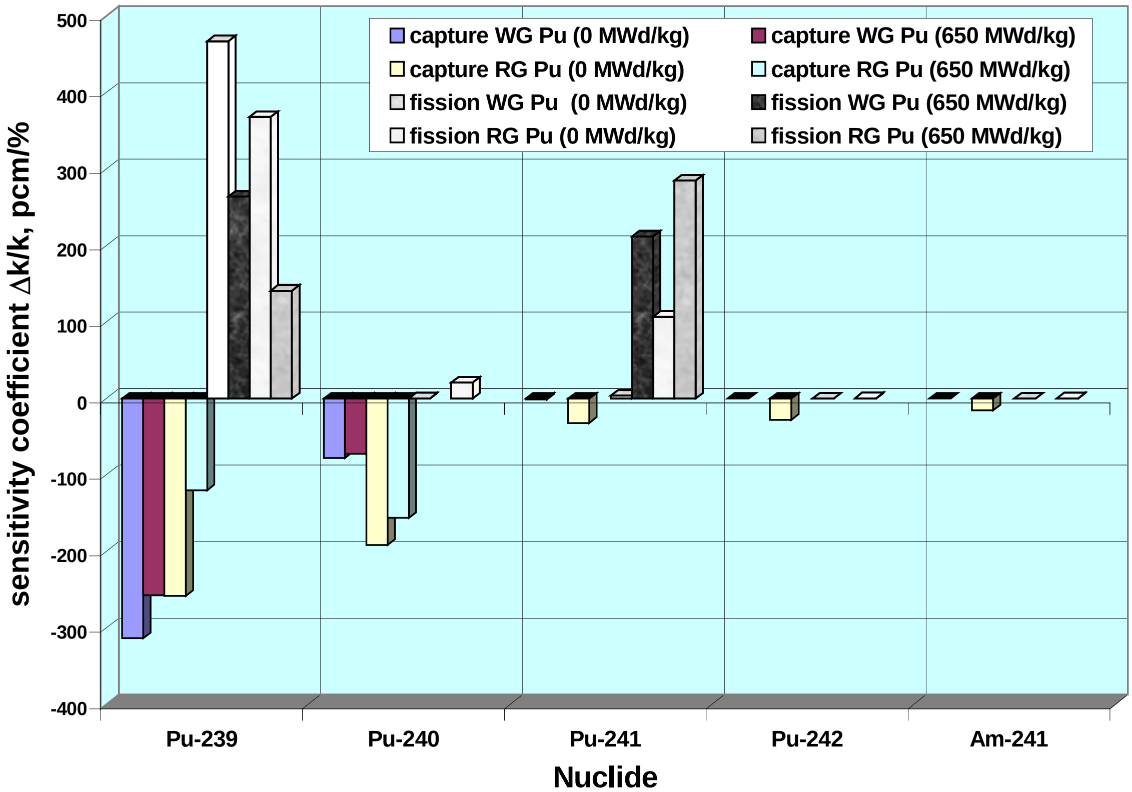

Fig. 1: Comparison of sensitivity coefficients for capture and fission for RG and WG plutonium for 0 and 650 MWd/kg HM burnup

4 Uncertainty on the reactivity for WG-Pu fuel

The k_∞ uncertainty (Ic) corresponds to :

$$Ic = \sqrt{Sc\,Dc\,Sc^t}$$

where :

Sc is the sensitivity matrix for the isotope c
Dc is the dispersion matrix for the isotope c

Calculations are performed with dispersion matrix given in reference [4]. Sensitivity coefficients are calculated with a direct method on 15 groups of energy (JEF standard energetic mesh).

Table 5: Uncertainty on the reactivity at 0 MWday/kg

	Pu 239	Pu 240	Pu 241
Uncertainty of k_∞	$5.41\ 10^{-3}$	$2.3\ 10^{-3}$	6.10^{-5}

	FISSION	NU	CAPTURE
Uncertainty of k_∞	$2.\ 10^{-3}$	$2.2\ 10^{-3}$	5.10^{-3}

Uncertainty of k : 0.58 %

k_∞ = 1.57934 ± 0.00916

Table 6: Uncertainty on the reactivity at 650 MWdays/kg

	Pu 239	Pu 240	Pu 241	Pu 242	Am 241
Uncertainty of k_∞	$2.8\ 10^{-3}$	$3.6\ 10^{-3}$	3.810^{-3}	$1.6\ 10^{-3}$	$1.0\ 10^{-3}$

	FISSION	NU	CAPTURE
Uncertainty of k_∞	$1.9\ 10^{-3}$	$2.4\ 10^{-3}$	$5.4\ 10^{-3}$

Uncertainty of k : 0.62 %

k_∞ = 1.14682 ± 0.00711

5 Conclusion

At 0 burn-up, the reactivity is mainly governed by the Pu-239 capture and fission. Pu-240 capture and Pu-241 fission have a great influence too.
Although there is less Er-167 than Er-166 in natural Erbium, Er-167 has a greater impact on the reactivity. Sensitivity coefficients of the other isotopes of Erbium are lower than 5 pcm/%.
At 650 MWdays/kg, only Plutonium isotopes have a great impact on the reactivity. The variation of the reactivity due to minors actinides cross section, is not greater than 15 pcm/% for a RG-Pu and 5 pcm/% for a WG-Pu.

For a WG-Pu, uncertainties on heavy nuclide cross sections lead to uncertainties on k_∞ equal to 0.58% (0 MWday/kg) and 0.62% (650 MWdays/kg). This can be explained by the fact that reactivity is mainly sensitive to isotopes having small standard deviations, the less well-known isotopes, on the contrary, have a lower influence on the reactivity.

6 References

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