EXTERNAL REPORT
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Report criticality dosimetry

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Contract information

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1 Introduction

Every few years, the SCK•CEN is involved in an international intercomparison exercise to test the performance of several dosimeters in a simulated criticality accident. This exercise is organized by CEA Valduc in France where there is access to the SILENE reactor, a reactor specially designed and built to simulate criticality accidents. SILENE is a compact reactor in which a fissile solution of uranyl nitrate can be introduced. To simulate the criticality accident, the control rod is slowly removed after introduction of the fissile solution. The environmental situation in close proximity to the reactor can be adapted as well, by changing the shielding configurations:

- Without shielding: mixed neutron and gamma radiation
- Lead shielding: preponderance of the neutron component
- Polyethylene shielding: preponderance of the gamma component
- Steel shielding: degraded energy neutron spectrum.

2 Description of the experiments

The intercomparison exercise took place from September the 27th until October the 1st. Five countries where involved in the exercise: France, Italy, Belgium, Japan and Greece. During that week two experiments were performed where several dosimeters were positioned at various distances from the reactor core. To measure the gamma dose, TLD700 was used (TLD material enriched with ^{7}Li to avoid sensitivity for neutrons). The neutron dose was measured using the criticality dosimeters developed at SCK•CEN. The criticality dosimeters are based on the activation of Au, Au covered with Cd, In and S to reconstruct the original neutron spectrum. In order to achieve this, the specific activities of the samples are measured through gammaspectrometry allowing determination of the samples responses. The spectrum can be reconstructed by using these responses in an iteration algorithm described by Doroshenko et al. The spectrum allows proper calculation of the neutron dose in terms of D*(10) [Gy] and H*(10) [Sv]

Besides our own dosimeters, some dosimeters were used provided by Landauer Inc.: FNTD's (fast nuclear track detectors) and Al_2O_3:C (luxel) with a mixture of ^{6}LiF to introduce neutron sensitivity. The results of these dosimeters will be provided later by Landauer.

In the first experiment, the dosimeters were irradiated in a mixed neutron and gamma field, so no shielding around the reactor core was used. During the second experiment, lead shielding was used, so the neutron component was preponderant. This allowed us to test whether there was a gamma response of the criticality dosimeters and a neutron response of the TLD700.

3 Results

3.1 Experiment 1: free evolution – no shielding

3.1.1 Results neutrondose:

Distance from the reactor core (m)	Specific activity (Bq/g)	Calculated dose (Gy)	Reference dose (CEA) (Gy)	Ratio calculated/measured	Calculated dose (Sv)
2	In: 8356 S: 127.03 Au: 180153.4 Au (Cd): 170759* *estimation based on other results	7.0	11.7 ± 0.5	0.60	77.501
4	In: 4132 S: 27.98 Au: 91250 Au (Cd): 27388	3.5	3.4 ± 0.2	1.04	42.295
6	In: 2589 S: 16.49 Au:44643 Au (Cd): 20459	2.2	1.72 ± 0.2	1.28	26.377

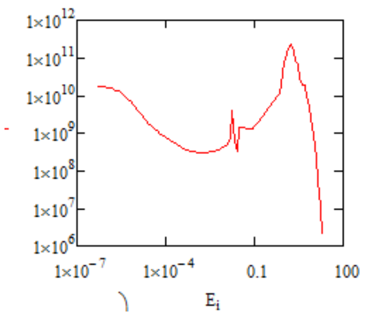

FIGURE 1: NEUTRON SPECTRUM EX1 - 2M

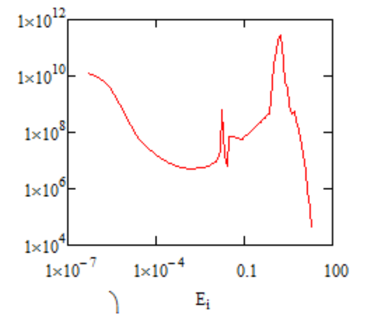

FIGURE 2: NEUTRON SPECTRUM EX1 - 4M

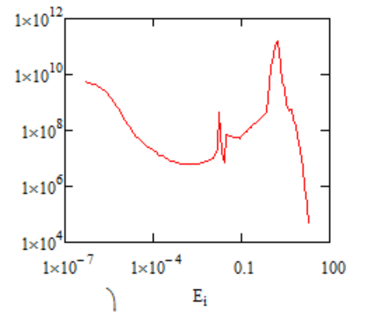

FIGURE 3: NEUTRON SPECTRUM EX1 - 6M

3.1.2 Results gammadose

Distance from the reactor core (m)	Calculated dose $H_p(10)$ (Sv)	Calculated dose K_a (Gy)	Reference dose (CEA) K_a (Gy)	Ratio calculated/reference	ζ-score
2	18.7	17.0 ± 4.2	15.5 ± 0.8	1.20	0.3
4	4.8	4.3 ± 1.1	4.92 ± 0.4	0.97	0.5
6	2.6	2.3 ± 0.6	2.64 ± 0.2	0.96	0.5

3.2 Experiment 2: free evolution – lead shielding

Distance from the reactor core (m)	Specific activity (Bq/g)	Calculated dose (Gy)	Reference dose (CEA) (Gy)	Ratio calculated/measured	Calculated dose (Sv)
2	In: 9993 S: 84.09 Au: 274573 Au (Cd): 267785	8.552	9.85	0.87	102.069
4	In: 3252 S: 19.48 Au: 78307 Au (Cd): 35235	2.74	3.10	0.88	32.842
6	In: 1564 S: 9.38 Au: 52912 Au (Cd): 40403	1.16	1.54	0.75	13.015

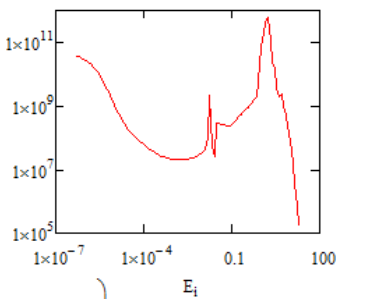

FIGURE 4: NEUTRON SPECTRUM EX2 - 2M

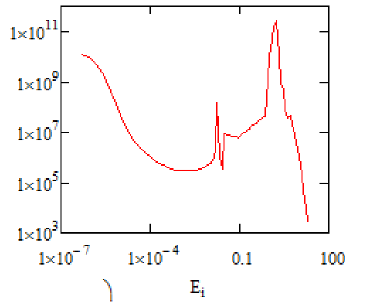

FIGURE 5: NEUTRON SPECTRUM EX2 - 4M

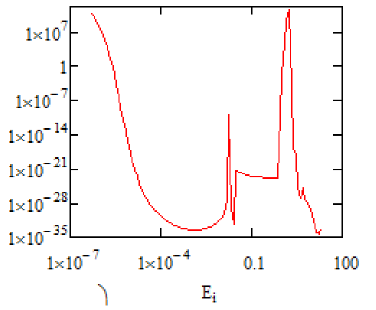

FIGURE 6: NEUTRON SPECTRUM EX2 - 6M

3.2.1 Results gammadose

Distance from the reactor core (m)	Calculated dose $H_p(10)$ (Sv)	Calculated dose K_a (Gy)	Reference dose (CEA) K_a (Gy)	Ratio calculated/reference	ζ-score
2	2.7	2.5 ± 0.6	0.94 ± 0.5	2.89	1.9
4	1.2	1.1 ± 0.3	0.57 ± 0.2	2.16	1.6
6	0.8	0.7 ± 0.2	0.45 ± 0.2	1.72	0.9

3.3 Conclusions

The international intercomparison exercise revealed that the criticality dosimeters work properly. The neutron dose can be recovered within an uncertainty window of 25%. Only one result (first experiment at two meter) differed for more than 30% from the reference value, but this can be explained by the fact that the gold foil covered with Cd wasn't present, so some data was missing for a proper reconstruction of the neutron spectrum. The dose was recovered using an estimation of the missing data, based on the results of the other experiments.

When the results of the gammadose calculations are compared to the reference values, one can immediately see the big difference between the two experiments. The results of the first experiment ended up with a ζ-score smaller or equal then 0.5. The ζ-values from the second experiment are much higher, but still lie between the acceptable boundaries. The fact that the uncertainties on the reference values in the second experiment are approximately equal to 50%, makes it difficult to determine the actual reference values. This can explain the difference between the reference values and the calculated values for the gammadose in the second experiment.

The international intercomparison exercise proofed that the system for criticality dosimetry at SCK•CEN works properly. In the case of a criticality accident, SCK•CEN is able to reconstruct the original dose within 25% uncertainty.