EXPERIENCE "BENCHMARK BETON" POUR LA DOSIMETRIE HORS CUVE DANS LES REACTEURS A EAU LEGERE

CONCRETE BENCHMARK EXPERIMENT : EX-VESSEL LWR SURVEILLANCE DOSIMETRY

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SYNTHÈSE :

L'analyse de la dosimétrie interne et externe de DOEL 1 a montré, en utilisant le code Sn DOT 3.5 couplé avec la bibliothèque VITAMINC, les mêmes écarts expérience-calcul pour tous les détecteurs devant et derrière la cuve.

Ces résultats semblent être contradictoires avec ceux obtenus dans plusieurs Benchmark (PCA, PSF, VENUS, ...) dans les mêmes conditions de calcul. En fait, on observe dans ce cas une tendance très prononcée à la décroissance du rapport calcul sur expérience (C/E) à mesure que l'on s'éloigne du cœur. Cette tendance particulière est principalement due à la surestimation de la section de diffusion inélastique du Fer.

On pourrait alors supposer qu'il existe un effet compensatoire dans la cavité de DOEL responsable de la remontée du rapport C/E. Cet effet pourrait être dû essentiellement à une exagération de la rétrodiffusion des neutrons due au béton. Une expérience de validation baptisée "Benchmark béton" a donc été décidée pour juger de la capacité des méthodes de calcul à traiter la rétrodiffusion.

Cette communication décrit l'expérience et présente les premiers résultats de comparaison expérience - calcul qui semblent montrer une surestimation de l'effet de rétrodiffusion dans les calculs.

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EXECUTIVE SUMMARY :

The analysis of DOEL-1 in-vessel and ex-vessel neutron dosimetry, using the DOT 3.5 Sn code coupled with the VITAMIN-C cross-section library, showed the same C/E values for different detectors at the surveillance capsule and the ex-vessel cavity positions. These results seem to be in contradiction with those obtained in several Benchmark experiments (PCA, PSF, VENUS...) when using the same computational tools. Indeed a strong decreasing radial trend of the C/E was observed, partly explained by the overestimation of the iron inelastic scattering. The flat trend seen in DOEL-1 could be explained by compensating errors in the calculation such as the backscattering due to the concrete walls outside the cavity. The "Concrete Benchmark" experiment has been designed to judge the ability of this calculational methods to treat the backscattering.

This paper describes the "Concrete Benchmark" experiment, the measured and computed neutron dosimetry results and their comparison. This preliminary analysis seems to indicate an overestimation of the backscattering effect in the calculations.

A former analysis of DOEL-1 [1] ex-core neutron dosimetry, using the DOT 3.5 Sn code coupled with the VITAMIN-C [2] cross-section library, showed the same C/E ratio values for different detectors at the surveillance capsule and the ex-vessel cavity positions. These results seem to be in contradiction with those obtained in several benchmark experiments (PCA, PSF, VENUS ...)[3-5] when using the same computational tools. Indeed a strong decreasing radial trend of the C/E was shown, partly explained by the overestimation of the iron inelastic scattering. For these reasons we thought that the flat radial trend observed in DOEL-1 results could be explained by compensating errors in the calculation, such as an overestimation of the backscattering effect from the concrete wall outside the cavity. In order to check the ability of these calculational tools to treat correctly this effect, a "Concrete Benchmark" experiment has been undertaken at SCK/CEN at Mol (Belgium). In this paper we will describe the experiment and present preliminary experimental results as well as calculated ones. We also compare them and outline preliminary tendencies.

Description of the experiment and results

Experimental device

It consists of a hollow concrete cylinder of 105 cm length and 10 cm thickness (inner diameter of 30 cm), surrounded by a 5 mm thick Aluminium cast. It is closed at its upper end by a 20 cm thick removable stop made of the same concrete (see Fig.1). The lower end of the cylinder is closed by the neutron source device made of 2 U-235 plates (93.5 % enriched, 188.5*80*0.2 mm) encapsulated in an aluminium cladding and bolted on a 20 cm thick mild steel cylinder. The role of this cylinder is to degrade the fission spectrum induced in the U-235 plate by the thermal neutrons coming from the BR1 thermal column. Indeed the whole system is loaded in the 1 meter diameter large cavity located in the vertical thermal column of BR1. The chemical composition of all components were accurately established. A particular attention was devoted to the concrete stop; indeed a 20 cm cubic block was made in parallel using the same concrete. This block was drying in the same conditions as the concrete device elements. At the moment we used the device, samples were taken from the cubic block at different positions (top, centre and bottom) and served for the concrete characterisation. Finally two compositions were adopted; the first one for the lower part of the stop (1/3rd of the thickness) and the second one for the remaining parts. The two compositions are differing just by their degree of moisture. The chemical composition of the concrete was ratio values for different detectors at the surveillance capsule and the ex-vessel cavity positions. These results seem to be in contradiction with those obtained in several benchmark experiments (PCA, PSF, VENUS ...)[3-5] when using the same computational tools. Indeed a strong decreasing radial trend of the C/E was shown, partly explained by the overestimation of the iron inelastic scattering. For these reasons we thought that the flat radial trend observed in DOEL-1 results could be explained by compensating errors in the calculation, such as an overestimation of the backscattering effect from the concrete wall outside the cavity. In order to check the ability of these calculational tools to treat correctly this effect, a "Concrete Benchmark" experiment has been undertaken at SCK/CEN at Mol (Belgium). In this paper we will describe the experiment and present preliminary experimental results as well as calculated ones. We also compare them and outline preliminary tendencies.

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Measurement results

Measurements were performed on the device central axis at different vertical positions (0, 30, 40, 50, 55, 57.5, 60, 62.5 and 65 cm). These positions are given relatively to the large cavity centre. The nearest position from the concrete stop is the one located at 65 cm which corresponds to 2 cm from the concrete stop. Rh-103(n,n')Rh-103m and In-115(n,n')In-115m radiometric dosimeters as well as Np-237(n,f) and U-238(n,f) miniature fission chambers are used. For each dosimeter two traverses were performed; the first one with the concrete stop and the second one without. The dosimeters were loaded in a cylindrical holder made of aluminium (1 mm thick) and covered with a cadmium sheet. The holder is introduced in the device after having the reactor power stabilised at 700 kW. The uncertainty on the monitoring of the BR1 reactor power is 2%. All the radiometric experimental results were expressed as end-of-irradiation relative activities. The U-238 fission chambers results are not reported in this paper as their analysis is still going on. Supplementary measurements are necessary to correct them for the U-235 contribution. The preliminary experimental results, for Np, Rh and In, are given in table 1 in the form of ratios of the activities with the concrete stop to the ones without. The uncertainty on the measured ratios is of the order of 7.3%. It results from the quadratic combination of the uncertainties on the activities (5%) with and without the concrete stop and the uncertainty due to the reactor power monitoring. One has to point out the difficulty of these measurements due to the low level of the fast flux. The fast neutron flux (E > 1 MeV) magnitude is of the order of 10^6 n/cm².s.

Computational analysis and results

The two configurations, with and without the concrete stop described above, were analysed using the DOT 3.5 transport code. The two runs were completed using the same R-Z geometrical model, shown in Fig.2. A very fine meshing (56R*102Z) was adopted, allowing us to follow accurately the spherical form of the BR1 cavity. The calculations were made in a fixed source mode with S8 and P3 approximations. The source was placed in the mesh located at the bottom of the mild steel. The thickness of the mild steel block was optimised in order to have an emerging neutron spectrum representative of the one encountered in the cavity beyond the pressure vessel of a PWR. All the aluminium claddings were represented in the geometrical model. The ENDF/B-V U-235 fission spectrum was used as energy distribution for the source. The macroscopic cross-sections were prepared for the different components using the AXMIX module and the 56-group ELXSIR library [6]. The flux spectra were then selected on the central axis and weighted by the considered dosimeters response functions. The BUTLER and SANTRY [7] evaluation was used for the Rh-103(n,n') reaction whereas we used the ELXSIR dosimetry file for the other reactions. The calculated results are also presented in the form of ratios of the reaction rates with the concrete stop to those without. Figures 3 to 5 illustrate the complete traverses along the central axis whereas in table 1 we give the particular results corresponding to the measurement locations.

Comparison of calculated and measured results and discussion

When considering these preliminary results, one can suspect a tendency to overestimate the backscattering in the calculation, especially for low energy threshold dosimeters. We thought that this can be explained by an overestimation of the concrete moisture in the calculation, as we took the concrete composition at the starting time of the experiment. We reduced the degree of moisture by a factor two and re-ran the calculation and this led to a 1% reduction of the calculated backscattering. An other possible reason of this overestimation is the S8 quadrature set used in the actual calculation; indeed we used the full-symmetric set as in the DOEL-1 analysis. We are planing to re-analyse this experiment using forward peacked biased quadrature set. Concerning the experimental programme, in addition to the U-235 fission chambers measurements going on, absolute flux measurements at the cavity centre are considered in order to check a possible influence of the presence or absence of the plug on the neutron source even though this can reasonably be considered as negligible.

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TABLE-1: Comparison of measured and calculated ratios end-of-irradiation activities with and without concrete stop

Measurement	Np-237			Rh-103			In-115		
Location	C	E	C/E	C	E	C/E	C	E	C/E
0.0	1.007	0.987	1.021	1.002	1.000	1.002	1.002	1.000	1.002
30.0	1.029	0.985	1.044	1.012	1.040	0.973	1.008	1.030	0.979
40.0	1.046	1.059	0.987	1.020	1.040	0.981	1.013	1.030	0.983
50.0	1.094	1.080	1.013	1.052	1.040	1.012	1.034	1.040	0.994
55.0	1.144	1.124	1.018	1.089	1.100	0.990	1.058	1.090	0.971
57.5	1.181	1.130	1.045	1.116	...	...	1.077	...	...
60.0	1.226	1.151	1.065	1.151	1.000	1.151	1.100	1.090	1.009
62.5	1.291	1.183	1.091	1.205	...	...	1.137	...	...
65.0	1.394	...	...	1.295	...	...	1.200	...	...

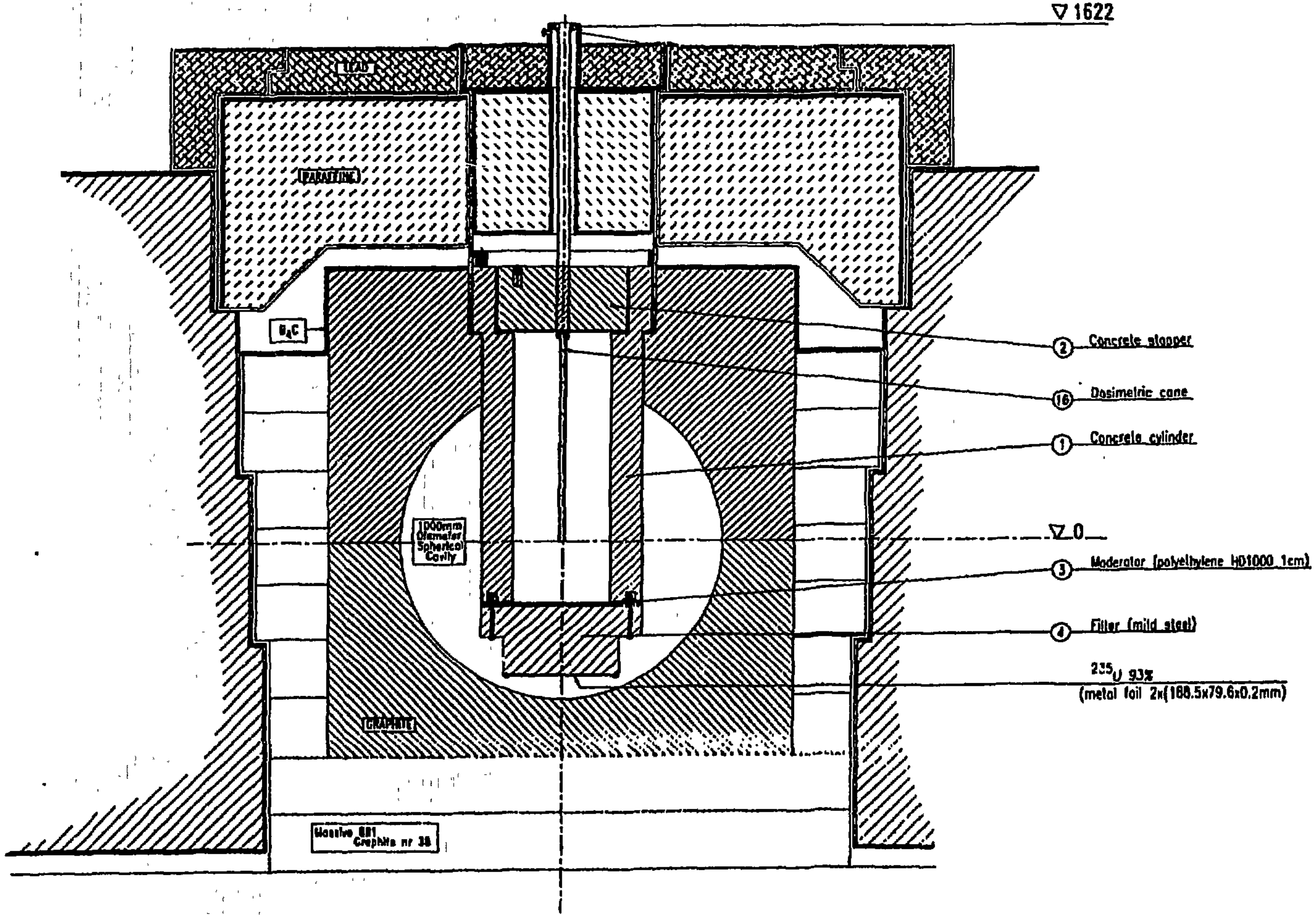


FIG.1 —*Vertical section of the "Concrete Benchmark" device in the BR1 large cavity.*

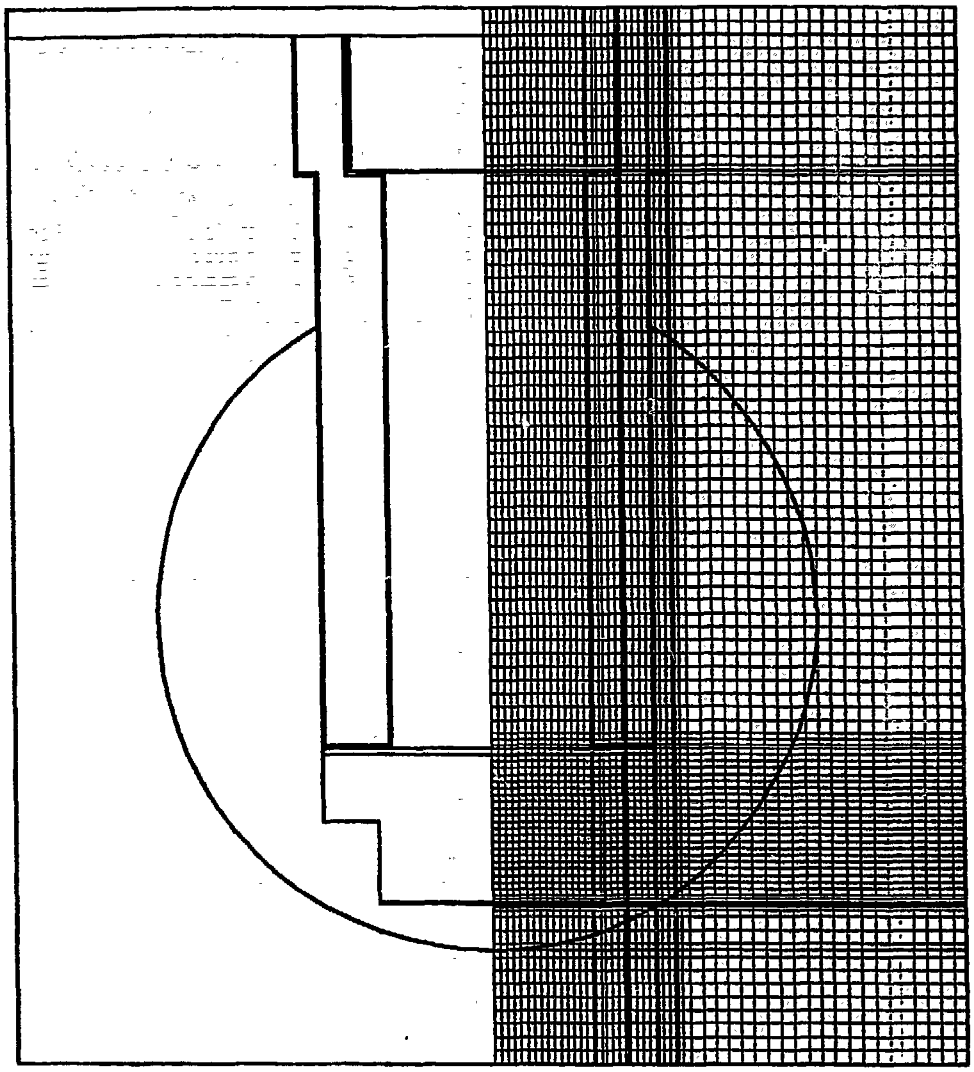


FIG.2-*R-Z calculational model for the "CONCRETE BENCHMARK" Experiment*

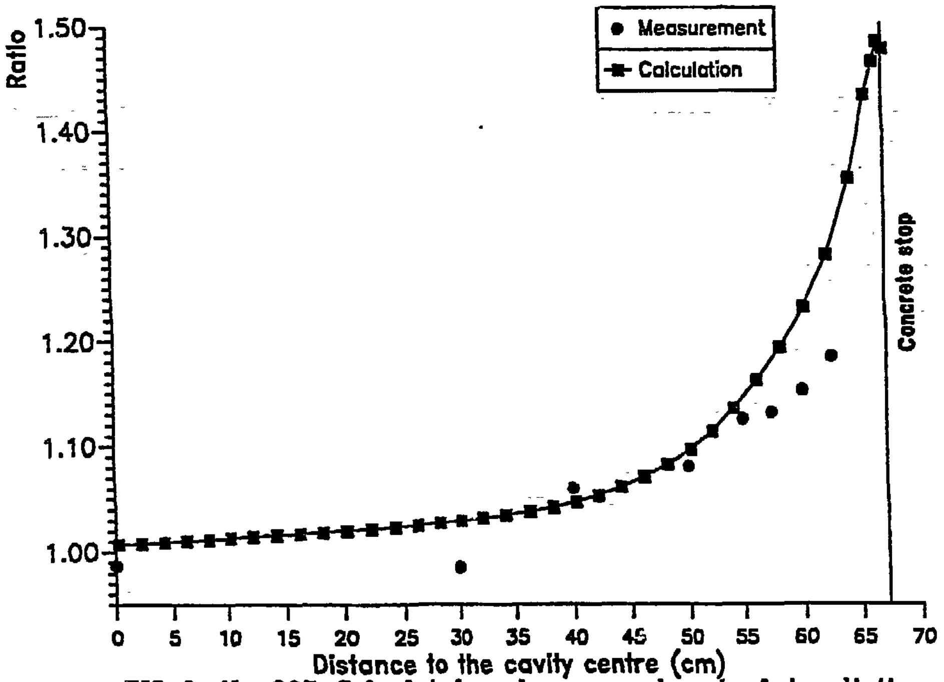


FIG-3: Np-237 Calculated and measured end-of-irradiation activity ratios with and without concrete plug

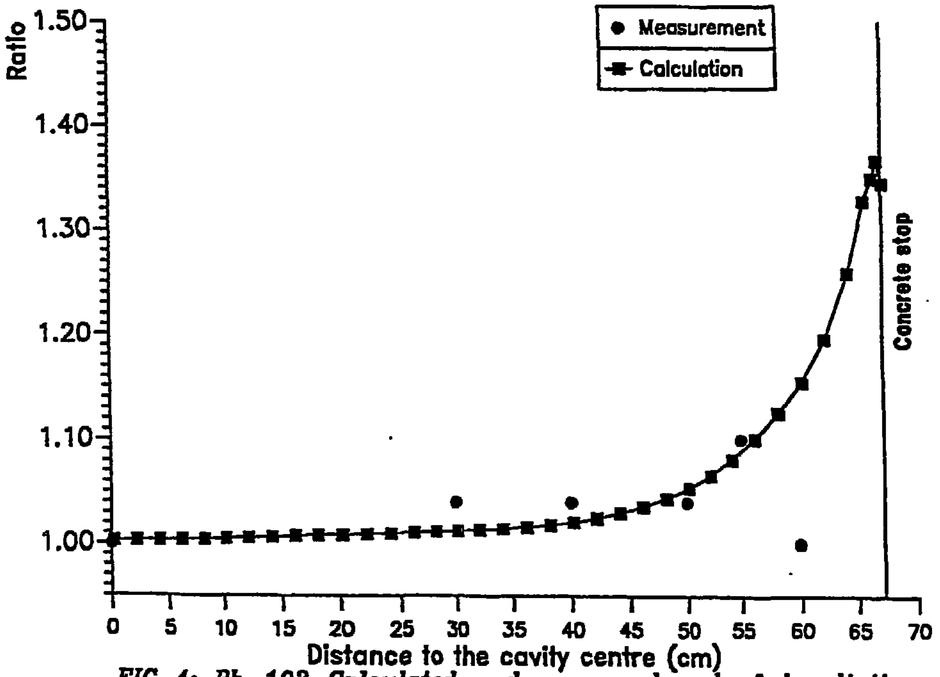
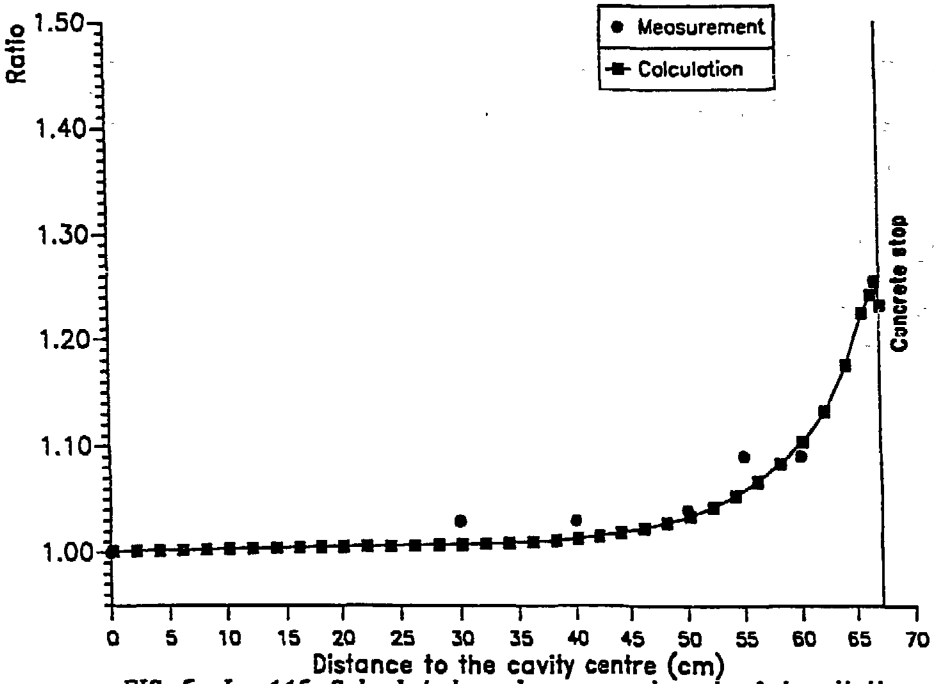


FIG-4: Rh-103 Calculated and measured end-of-irradiation activity ratios with and without concrete plug



FIG–5: In–115 Calculated and measured end–of–irradiation activity ratios with and without concrete plug

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