

EMISSION RATE CORRECTIONS FOR $^{241}\text{AmBe}$ SOURCES IN MANGANESE BATH OF LNMRI/IRD

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Abstract: This work tries to get better: uncertainties and accuracy for determination of bath losses. With simulation is possible to individualize calculations from all the loss components, for each specific measurement. A regression model is also evaluated based on an old and a new proposed model.

Keywords: manganese bath, monte carlo simulation, neutron metrology, neutron sources.

1. INTRODUCTION

The emission rate of a neutron source (Q) measured by the method of the Manganese Bath System [MBS] (figure 1) is determined through the measure of the activity of saturation of the solution (A). The saturation activity represents the moment in that the rate of nuclei of manganese activated by the capture of thermal neutrons it is same the rate of decline of the activated manganese. This value is reached asymptotically after some hours of irradiation of MBS, with the source placed in your geometric center. For that activity to give the value of Q is necessary, however, to accomplish three types of corrections.



Fig. 1. The LNMRI/IRD Manganese Sulfate Bath.

The first is the efficiency (ϵ) of the detector NaI(Tl), submerged in the solution, in the decay count of the gamma radiation of the nuclide produced by the neutron activation $^{55}\text{Mn}(n,\gamma)^{56}\text{Mn}$. The second is due to capture of thermal neutrons for other present nuclei in the solution, that is

easily determined through the ratio among the macroscopic cross sections of thermal capture of the manganese and of the other nuclei of the solution (H, S and O), forming a fraction (F). The last correction, (K), it is relative to the losses due to the escape of neutrons from the Bath (L), fast capture of neutrons from solution (N), and neutron captured by the source material and its immersion systems (S).

In this way, the mathematical model that represents this physical reality it can simply be expressed through the equation (1).

$$Q(t) = A(t) \cdot \frac{1}{\epsilon} \cdot \frac{1}{F} \cdot K(N, S, L) \quad (1)$$

Nowadays, the losses due to escape and the fast capture are calculated starting from logarithmic regressions [SCHUCH, 1978]^[1] of experimental data; determined through a study where the losses above were obtained for different spectra, solution concentrations and tank dimensions. The loss regarding capture for the material of the source and your immersion system was not determined in that study and for that it doesn't compose the correction now K of BSM of LNMRI/IRD.

The simulation of MBS comes as an opportunity to determine all the losses that it composes K and to revise the values of those that are already obtained. The system of the bath of sulfate of manganese of LNMRI/IRD was modeled in MCNP4C2^[3] and the calculation of K was accomplished for sources of $^{241}\text{Am-Be}(\alpha,n)$, one of 37 GBq (Brazilian Standard for neutron fluence) other 185 GBq and another 592 GBq, all shown in figure 2.

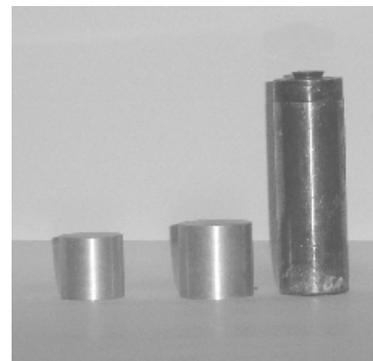


Fig. 2. $^{241}\text{AmBe}(\alpha,n)$ sources from LNMRI/IRD simulated in calculations of N , S e L . From left to right are shown, respectively: $^{241}\text{AmBe}(\alpha,n)$ from 37, 185 and 592 GBq.

A calculation similar to the presented in this work, it was accomplished in National Physical Laboratory [ROBERTS,

2001]^[4], England. The results of the calculations were considered appropriate for being implemented as correction factors for the emission rate of neutron sources in manganese bath.

2. THE MODELLING OF BSM-LNMRI/IRD

In the simulation, MBS of LNMRI/IRD is a spherical tank with a meter of internal diameter and fifteen millimeters of thickness of stainless steel (Figure 3). This still possesses an opening in the top, which in the physical tank is used in three situations: input of the source, an agitator's input, which is to homogenize the activated solution, and last, input of a NaI(Tl) detector.

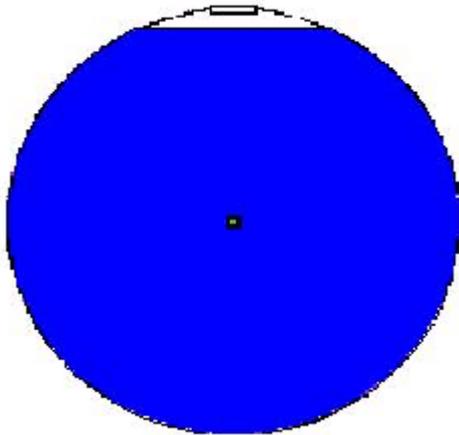


Fig. 3. Graphical mcnp output from simulated MSB.

The sources considered in the simulation were those of routine use of the neutron laboratory and specifically used to disseminate your metrological capacity. The model of the source $^{241}\text{Am-Be}$ of 37 GBq is SN 366, manufactured by CEA (Figure 2 and 4), other source used from this manufacturer was from 185 GBq shown in figure 2. The source $^{241}\text{Am-Be}$ of 592 GBq, for being very old, doesn't possess registration on your model. This source was simulated being considered its dimensions (Figure 2 and 5). The spectra of all simulated sources are based on ISO-8529/1-3 references [ISO-8529/1-3, 1989]^[3].

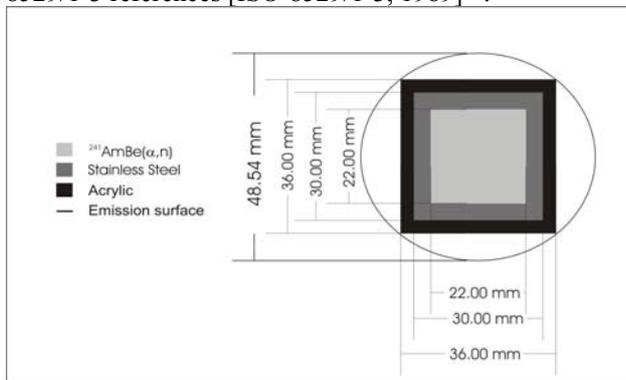


Fig. 4. Sketch from 37GBq $^{241}\text{AmBe}(\alpha,n)$ source simulated in MCNP. Cylinder symmetrically constructed with height equal width.

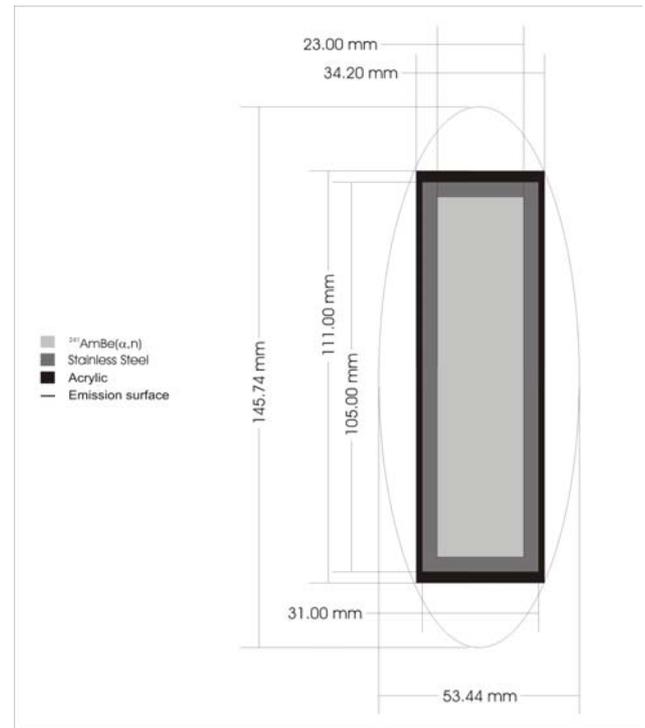


Fig. 5. Sketch from 592GBq $^{241}\text{AmBe}(\alpha,n)$ source simulated in MCNP. Height different from width.

The capture of fast neutrons for the solution (N) it is due the reactions (n,α) and (n,p) . These types of reactions have a value threshold of energy of the neutron so that they have larger probability of happening. Therefore, that fast capture is only important when the medium energy of the neutrons emitted by the source it is superior to this threshold of energy. The principal nuclei that make this reaction type in the solution are the sulfur $[(n,\alpha);(n,p)]$ and the oxygen $[n,\alpha]$. The calculation of N was accomplished being selected the tally F4 of MCNP4C2, being considered the reactions above, associated to a card multiplier that contains the volume of the solution and the atomic density (atoms/barn.cm) of the element that interacts for capture of fast neutrons.

The calculations of the neutron capture for the source and for your immersion system (S) it was also accomplished with the tally F4 and a card multiplier, but the calculation was accomplished separately for the acrylic (glass), for the stainless steel (capsule of the source) and for the radioactive material.

In the case of the escape of neutrons of the Bath (L), this was estimated with the tally F1. This tally was defined in a concentric external spherical surface of the tank and it represents the number of particles that cross the surface in any direction.

3. RESULTS

3.1 Simulated cylindrical sources

The K-factor is determined by the combination of N, S and L through the equation (2). This correction enters in the equation (1) as a multiplier, that is, any variation in K is applied directly in the calculation of the emission rate of the neutron source.

$$K = \frac{1}{(1 - N - S - L)} \quad (2)$$

It is observed that in relation to the values of the components N, S and L now used, the calculation with MCNP4C2 presented larger value in all these components. The capture for the source and your immersion system, that it is not considered in the current model, was shown important mainly for sources of larger volume. Being compared the value of N of the simulated radioactive sources, it is noticed that this value depends more of the spectrum than of the size of the sources. Already the escape of neutrons of the Bath (L), besides the spectrum, it also depends on the dimension of the source. The components N, S and L of both models were used to calculate to corrections K in the **table 1**.

Both components of (N), due the reactions (n,α) and (n,p), presented great disagreement with the values used now. Part of this disagreement can be explained by the updating of the cross sections. For instance, the microscopic cross section of fast capture of the oxygen, calculated in the beginning of the decade of 1970, it underestimates the neutron capture with superior energy to 7 MeV, if compared with the O(n,α) cross section of MCNP4C2 library [ROBERTS, 2001]^[4].

Table 1. Comparison between the K-factor determined through of MCNP4C2 and the old model.

Source	K		Increase with MCNP4C2
	MCNP4C2	Old model ^[1]	
²⁴¹ Am-Be (37 GBq)	1.0621	1.0329	2.82%
²⁴¹ Am-Be (592 GBq)	1.0733	1.0330	3.90%

Besides the calculation of the K-factor, an abbreviation study was accomplished on the influence of small variations of some parameters that affect the value of K and that for consequence contribute to the uncertainty in the value of the emission rate of neutrons source. The perturbed parameters^[5] were: the density of the solution (1.359±0.012g/cm³), level of the solution (44.5 ± 0.3cm) and position of the source (0.0 ± 0.5cm). The **table 2** displays the contribution of these dispersions on the value of the uncertainty of Q.

Table 2. Uncertainty in the values of K relative to the emission rate of the neutron sources (Q).

	u _Q (K)/Q	
	²⁴¹ Am-Be (37 GBq)	²⁴¹ Am-Be (592 GBq)
Current model	0.62%	0.62%
MCNP4C2	0.27%	0.31%

3.2 Simulated cylindrical degenerated to spherical sources – Regression Model

Another point explored in this work was a mathematical approach based on the several values in size of the sources

studied. For that, the values from L, N and S were plotted and were created some curve trends to represent those components. After that, the values from K were also calculated and its plotting has been made. For leakage (figure 6) one simple linear trend was enough and its uncertainties are low compared with individual ones for assumption from linear adjustment. The extreme values from leakage varies from 1.35 to 1.55 for diameters from zero to 5.5 cm

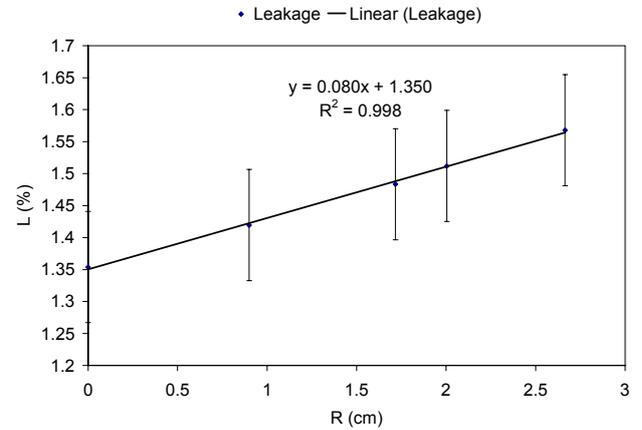


Fig. 6. Plotting linear trend for values of leakage from the bath in function of equivalent ray for neutron source.

In the case of fast neutron capture, the curve trend assumption was a cubic polynomial, as shown in figure 7. Curve adjusts with a good approximation to the point values and has extreme values from 3.38 to 3.50 %

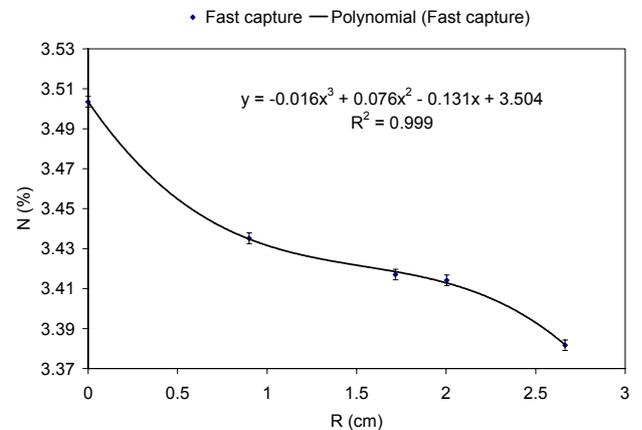


Fig. 7. Plotting curve for values of fast capture inside the bath in function of equivalent ray for neutron source.

Curve used for adjustment of capture by source encapsulation and materials (figure 8) in the bath was the most difficult to find. The predicted uncertainty in simulation and the curve approach let some point out of prediction. This is minor in part because of the S contribution for the K correction (equation 2) and was corrected for this regression model by assumption of a bigger uncertainty order.

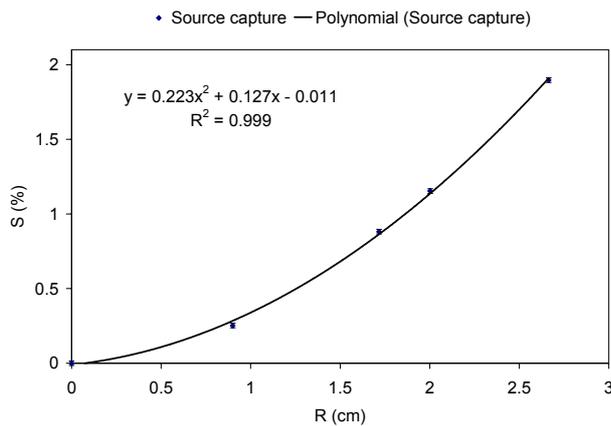


Fig. 8. Plotting curve for values of source capture inside the bath in function of equivalent ray for neutron source.

Finally, it was analyzed the combined values in accordance to equation 2 and the values were plotted in figure 9. As for the last graphic, the curve used in regression was a quadratic one.

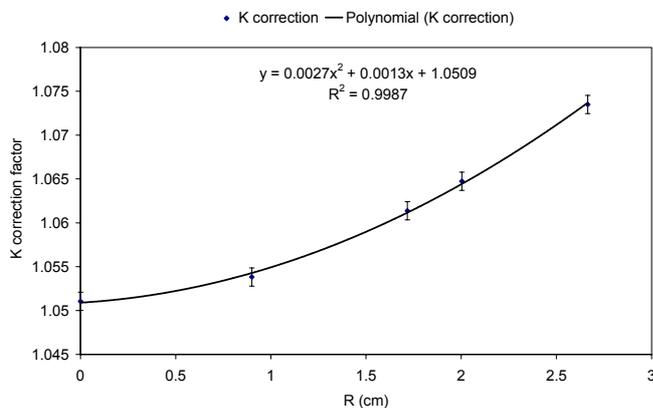


Fig. 9. values and curve k correction in function of equivalent ray for neutron source.

4. CONCLUSION

A great difference was observed in the values of K calculated by MCNP4C2 and the current model, which is based on logarithmic regressions of experimental data. Probably that is due to the available measure conditions at that time (1970) and for MCNP4C2 to use groups of more current cross sections.

The contribution of the uncertainty of K in Q for MCNP4C2 presented smaller value than the one that is now estimated through the experimental data.

In spite of the calculations accomplished with MCNP4C2 they be reliable, an investigation on the causes of the disagreement in the values of K and a wider analysis of uncertainty should be made before it is assumed the values of K of MCNP4C2 as the new assumed corrections of the emission rate of the neutron sources simulated.

The regression models show good agreement to the simulated individual sources in this work. For future, an extensive study for other neutron source as ^{252}Cf and

^{241}AmB should be made and other values from concentrations from the bath.

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