2009 International Nuclear Atlantic Conference - INAC 2009
Rio de Janeiro, RJ, Brazil, September27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-03-8

SOFTWARE FOR DETERMINATION OF THE THERMAL NEUTRON FLUX IN A NUCLEAR REACTOR

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ABSTRACT

In this study thermal neutron flux distribution was performed using the activity of the irradiated activation detectors: Au and In foils. The neutron flux in the IEA-R1 nuclear reactor at IPEN/SP in the pneumatic station was then house software and the results were compared. The data permits a discussion about the performed of this software.

1. INTRODUCTION

An analytical measurement is usually performed aiming to quantify elements (i.e., the composition) of a given species in a defined mass or volume. The (n,γ) nuclear reaction produced in a nuclear reactor is very used for analytical works. The neutron activation procedure combined with computerized high-resolution gamma-ray spectrometry offers nondestructive and multi-element routine analysis needed in such areas (environmental monitoring, geochemistry, medicine, etc) and technological processes. Nuclear reactors, mainly thermal neutron reactors, are very useful for this kind of analyses because a lot of elements could be quantified (about 75 elements less than 0.01 µg can be determined). To performed theses measurements the Instrumental or Parametric procedure of neutron activation can be applied [1]. The Instrumental technique is performing using standard while in the Parametric procedure the thermal neutron flux must be obtained. In this study thermal neutron flux distribution was performed using the parametric procedure. For this purpose the activity of the irradiated activation detectors (Au and In foils detectors) are obtained using in-house software which correlated the measured parameters with the constants physics involved. The results for Au and In detectors were compared.

2. NEUTRON FLUX DISTRIBUTION IN THE IEA-R1 NUCLEAR REACTOR

In a nuclear reactors fast neutron are first produced in the fission reactions where the energy distribution of the prompt fission neutrons following the Watt's spectrum. These neutrons are gradually slow down due all the collision with the atoms of the moderator and as result the thermal neutron flux distribution. These thermals neutron are in equilibrium with the atoms of the medium and theirs velocity behavior to the follow the Maxwell- Boltzmann distribution. The epithermal neutron flux distribution is also present and it could be significant in function of the irradiation position, and it also must be also determined.

General Features IEA-R1 reactor is a pool type (2-4 MW), light water cooled and moderated, and graphite and beryllium reflected research reactor. When an activation detector (AD) is irradiated in a neutron flux, its induced activity is due to both thermal and epithermal neutrons, as given by:

$$A_b^{\infty} = A_t^{\infty} + A_e^{\infty} \qquad (1)$$

Where A_b^{∞} is the saturation activity of a bare AD foil; At^{∞} is the activity due to thermal neutrons and A_e^{∞} is the activity due to the epithermal ones. To know the activity due to the thermal neutrons alone, the Cadmium ratio techniques have been used [1]. For this purpose, we define the *Cadmium ratio* as:

$$\mathrm{R}_{cd} = A_b^{\infty} / A_{cd}^{\infty} \qquad (2)$$

where $A_b^{\ \infty}$ is the saturation activity of the Cadmium covered foil. Although being an excellent filter to thermal neutrons, Cadmium is not fully transparent to the epithermal ones, so it is usual to introduce a correction factor [2] called *Cadmium factor* [F_{cd}], and the equation (1) can now be written as:

$$A_b^{\ \infty} = A_t^{\ \infty}[1 - \mathrm{F}_{cd} / \mathrm{R}_{cd}] \qquad (3)$$

where R_{cd} can be obtained experimentally from the ratio $A_b^{\infty} / A_t^{\infty}$ and F_{cd} from reference [2]. The thermal neutron flux is then obtained from:

$$\phi_t = A_t^{\ \infty} / \sigma_{act} . k_t \qquad (4)$$

where σ_{act} is the activation cross- section
k_t *is* the thermal flux perturbation factor [3].

3. EXPERIMENTAL PROCEDURE AND RESULTS

For this purpose, the activation detectors (see table 1) were irradiated in the IEA-R1 nuclear reactor at IPEN/SP. Each par detectors (foil bare and Cd covered) was sealed into individual polyethylene bags and irradiated at the same position allowing the simultaneous activation of them. After that, we obtained the gamma-spectra for each foil. A HPGe detector connected to an ADCAM multichannel analyzer and to a PC computer was used to measure the induced gamma-ray activity. The gamma-spectra analysis evaluation was performed using the IDF computer software [5] and the neutron flux distribution was performed using a software which correlated the measured parameters i.e., net area, efficiency of the selected gamma ray, irradiation time, counting time, decay time and the detector mass with the constants physics involved (the decay constant; the atomic mass, the Avogadro's number, the cross section for the selected capture reaction and the isotopic fraction and the intensity of the gamma ray). To illustrate the procedure performed by the software, in figure 1 is showing the screen that represent the step for the thermal neutron flux calculation and in figure 2 are presented the neutron flux results for several measurements performed in the IEA-R1 nuclear reactor using Au and In activation detectors. The estimated uncertainty was about 3.6 % to Au detector and 4.8 % to In for the same irradiation position at different reactor operation days.

Table 1. Activation Detector: parameters used for neutron flux calculation [1,4]

AD	Mass (mg)	Nuclear reaction	E_γ(keV)	σ (b)	*R_{cd}	Efficiency 10^{-5}
Au	1.02	$^{197}Au(n,\gamma)^{198}Au$	411.8	98.65 ± 0.09	10.1	0.0635±0.016
In	1.51	$^{115}In(n,\gamma)^{116}In$	1293.6	162.3 ± 0.7	11.8	0.0304±0.005

* mean value for irradiation at the same position (pneumatic station)

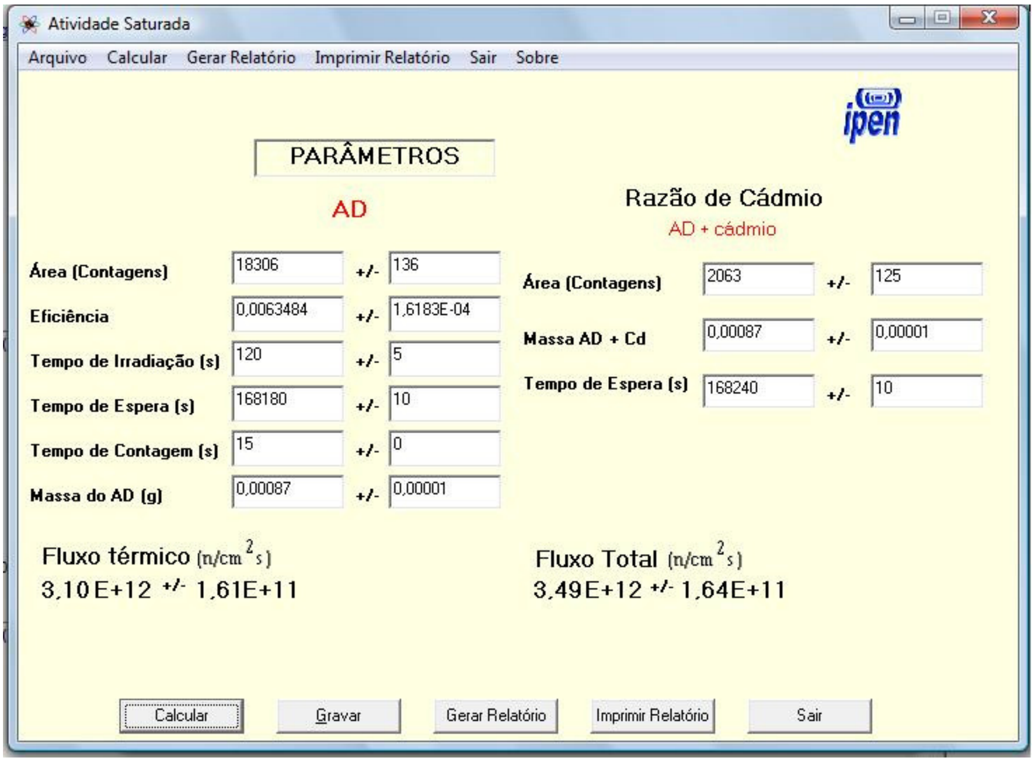

Figure 1. Software - thermal neutron flux calculation

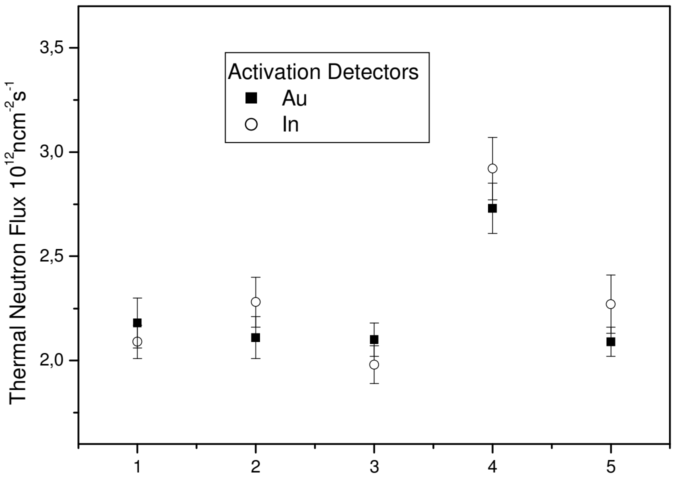

Figure 2. Thermal neutron flux distribution using Au and In activation detectors

According to the parametric procedure it is necessary to determine the efficiency of the gamma detector but, considering experiments which involving the analysis of a many samples, this method became agile because it is possible to obtain the concentration of several activated elements in each irradiation. However the associated uncertainly depends on the nuclear parameters involved (mainly cross section) as well as the experimental conditions (mainly detector efficiency).

4. CONCLUSIONS

The present study suggests that the software developed based on the parametric procedure of neutron activation analysis can be an agile and precise alternative for thermal neutron flux determination.

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