International Conference
Nuclear Energy for New Europe 2003
Portorož, Slovenia, September 8-11, 2003
http://www.drustvo-js.si/port2003

Fast Neutron Spectrum in the Exposure Room of the TRIGA Mark II Reactor in Ljubljana

Edvard S. Krištof
"Jožef Stefan" Institute
Jamova 39, SI-1000 Ljubljana, Slovenia
Edvard.Kristof@ijs.si

ABSTRACT

In this paper a description of the high energy neutrons at a usual position in the dry cell of our reactor is given. Neutrons emerging from the graphite reflector enter the exposure room through the horizontal shaft. At the irradiation position samples of detection materials were irradiated. After irradiation γ-ray spectra were measured and from the saturation activities the spectrum was calculated.

1 INTRODUCTION

Our dry cell is often used for irradiation with thermalized fluxes smaller than 10^8 $cm^{-2}s^{-1}$. In the last few years irradiation of minerals, biological samples and semiconductors was carried out. The ratio of fast flux Φ_f and conventional thermal flux Φ_t is $\Phi_f / \Phi_t \cong 0{,}03$. In spite of that fact the apparatus is used for some irradiation with fast neutrons in the absence of a fission plate due to its easy handling. However, the fast neutron spectrum must be known for evaluation of the irradiation data of material such as proton recoil detectors. For this reason, samples of materials that are well known in reactor metrology were irradiated at the standard position. After every irradiation gamma ray spectra were measured and from the saturation activities the spectrum was calculated.

2 IRRADIATION SET-UP

A simplified vertical cross-section through the essential part of the device is shown in Figure 1. Neutrons, originating in the reactor core, enter the dry cell through the horizontal shaft. They pass at least one meter of graphite and 70 cm of air. So we have at the standard irradiation position S prevailingly scattered neutrons with an addition of transmitted neutrons at higher energies.

Irradiation usually begins by lowering the sledge with the fastened sample into the room, and finishes by lifting it back.

3 IRRADIATION AND SAMPLES

The whole irradiation was performed at full reactor power of 250kW. Each irradiation was monitored by a foil of copper or by an approximately 50μm thick golden foil. Reactions which were selected for this presentation are ^{197}Au(n,γ) with bare diluted gold, ^{197}Au(n,γ) with diluted gold under cadmium cover, ^{63}Cu(n,γ) under cadmium cover, ^{96}Zr(n,γ) under cadmium cover, ^{98}Mo(n,γ) under cadmium cover, and threshold reactions ^{24}Mg(n,p), ^{27}Al(n,α), ^{27}Al(n,p), ^{64}Zn(n,p), ^{115}In(n,n'). Some of reactions will be added in future. Thickness of cadmium cover is 0.782 g cm^{-2}. Neutron reaction cross section data are taken from [1]. These data were processed into 20 groups per decade structure with a flat weighting spectrum. Other data necessary for the evaluation are taken from [2,3,4,5].

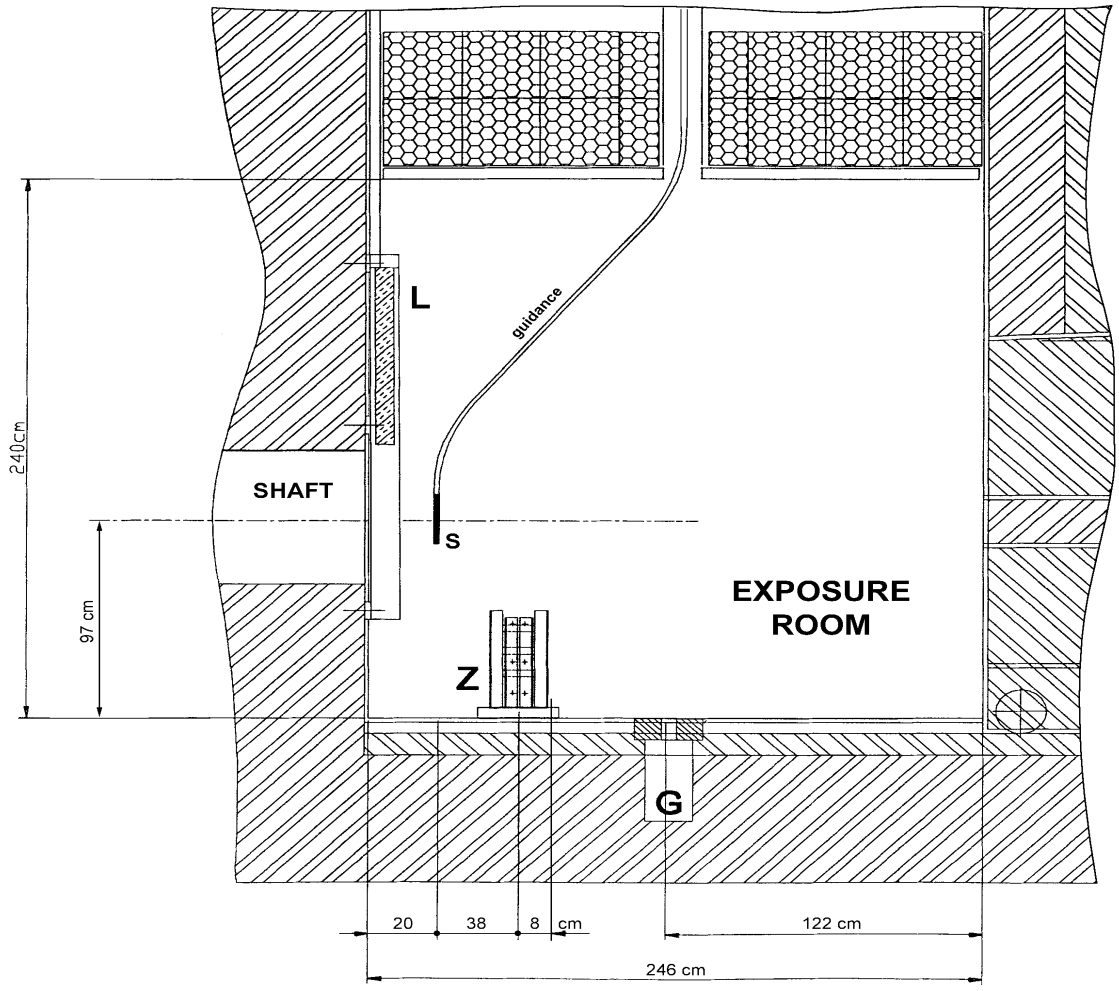

Figure 1. Simplified vertical cross-section through the dry cell.
Letters S, L, and Z denote the usual irradiation position, the shutter, and the shielding around the stored fission plate, respectively.

4 COMMENTS AND RESULT

Only the neutrons over 100keV contribute to the saturation activity of the five threshold reactions used. Let a_i be the measured saturation activity of the i^{th} threshold reaction and α_i the corresponding saturation activity calculated by the use of the curve shown in Figure 2. Accordingly, the number

$$\varepsilon = \sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N}\left(\frac{\alpha_i - a_i}{a_i}\right)^2} = 0.014 \ , \qquad \text{N=5} \tag{1}$$

could serve as a measure of the reliability of the calculation in the high energy region.

The measured neutron spectrum φ(E) at energies over 100keV is shown in Figure 2. A recess between 2MeV and 5MeV is evident. This shallow lies in the resonance region of the total cross section of ^{12}C [6]. A more detailed analysis reveals, that we can trust a shape at a chosen energy E if it is extended over an interval greater than (0.8E, 1.3E). It can also be observed that the influence of the scattering is strong enough so that the minimum at 3.7MeV appears close to the large resonance at 3.5MeV, and the little peak at 5.9MeV arises close to the pit at 6MeV in the total cross section of carbon.

The value

$$\phi_f = \int_{100\,keV}^{20\,MeV} \varphi(E)dE = 1.54(1 \pm 0.05)\cdot 10^6\, cm^{-2} s^{-1} \tag{2}$$

is the fast neutron flux at the position S in the exposure room. The error in this value contains the error of computation as well as the contribution of the uncertainties of all the individual γ-spectrometric measurements.

5 CONCLUSION

Fast neutron flux and fast neutron spectrum at the usual irradiation position in our dry cell are known within limitations given in paragraph 4.

6 ACKNOWLEDGEMENT

I would like to thank Bojan Huzjan, Janez Jezeršek, Darko Kavšek, Bojan Oman, Gvido Pregl, Matjaž Ravnik, Marko Rosman and Dušan Rudman for their kind support. Further I would like to thank Roza Pergarec for reading the text, and young fellows Mateja and Miha for their help in computer editing of this contribution.

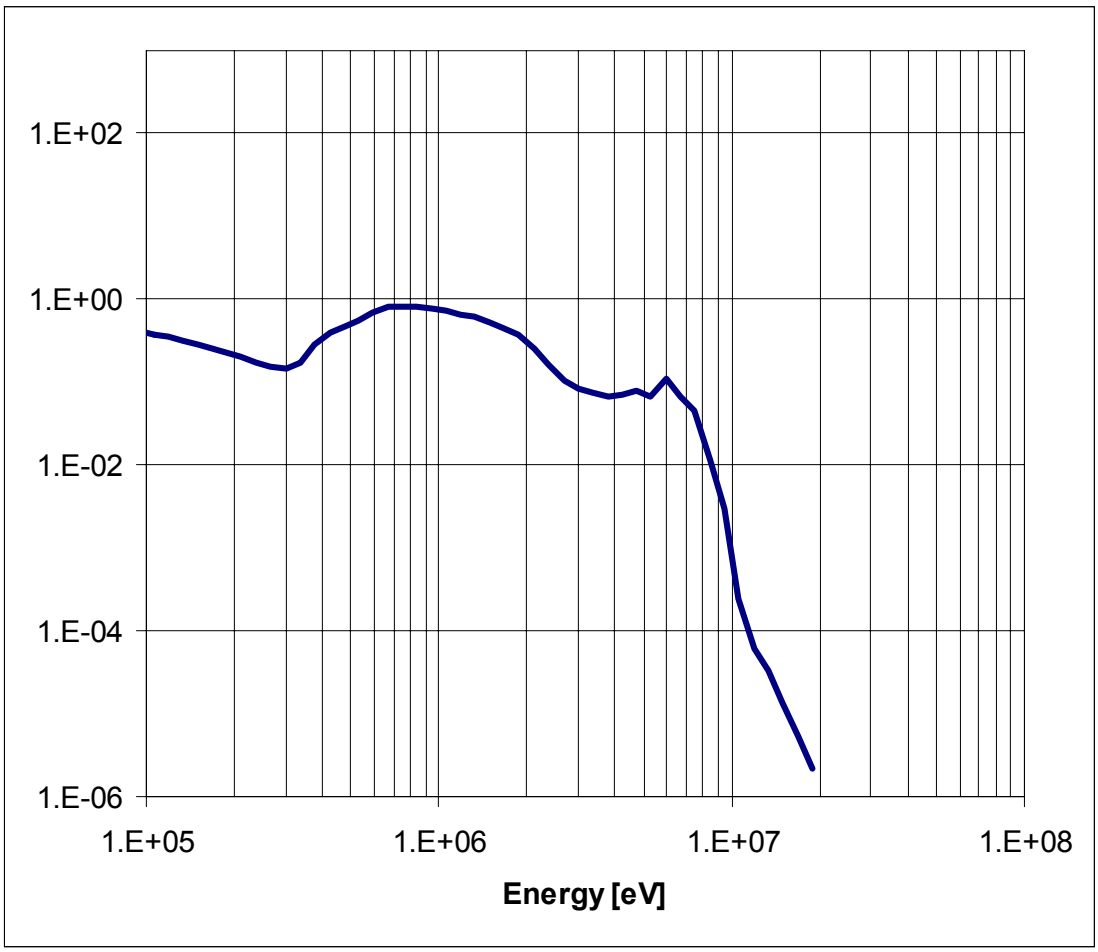

Figure 2. Fast neutron spectrum at the standard irradiation position in the exposure room at reactor power of 250kW.

7 REFERENCES

[1] Table of the Nuclides, http://www.dne.gov/CoN/…

[2] JEF-PC, A Personal Computer program for Displaying Nuclear Data from the Joint Evaluated File Library, OECD Nuclear Energy Agency, Issy-Les-Moulineaux, France, 1997.

[3] N.G.Gusev and P.P.Dmitriev, Quantum Radiation of Radioactive Nuclides, Pergamon Press, Kronberg-Taunus, Germany, 1975.

[4] J.H.Baard, W.L.Zijp, H.J.Nolthenius, Nuclear Data Guide for Reactor Neutron Metrology, Kluver Academic Publishers, Dordrecht, The Netherlands, 1989.

[5] W.Seelman-Eggelbert et al, Karlsruher Nuklidkarte, 6th edition, Kernforschungszentrum Karlsruhe, 1995.

[6] John L. Lamarsh, Introduction to Nuclear Engineering, Addison-Wesley Publishing Company, Reading, USA, 1975, Fig 3.3.