Annals of Nuclear Energy 42 (2012) 131–134

Contents lists available at SciVerse ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

The effect of graphite thermal column around the newly designed large irradiation channel of GHARR-1 on neutron flux distribution

M. Asamoah [a,*], O. Gyampo [a,b], B.J.B. Nyarko [a,b], E.H.K. Akaho [a,b]

[a] *Ghana Atomic Energy Commission, National Nuclear Research Institute, P.O. Box LG80, Legon, Accra, Ghana*
[b] *University of Ghana, School of Nuclear and Allied Science, P.O. Box AE1, Atomic, Accra, Ghana*

A R T I C L E I N F O

Article history:
Received 31 July 2011
Received in revised form 17 November 2011
Accepted 23 November 2011
Available online 2 January 2012

Keywords:
Neutron
Flux
Thermal column
Graphite

A B S T R A C T

Monte Carlo N-Particle code (MCNP-5) was employed to simulate the neutron flux profile in a newly designed irradiation site surrounded by a graphite thermal column for Large Sample Neutron Activation Analysis, in the Ghana Research Reactor-1. The results shows that the average thermal neutron flux in the irradiation channel surrounded with 6 cm thick graphite was 5.45×10^{10} n cm^{-2} s^{-1} as compared with 1.74×10^{10} n cm^{-2} s^{-1} when there is no graphite around the irradiation channel. This shows an increase in the thermal neutron flux in the irradiation channel by a factor of 3.13. The thermal neutron flux gradient decreased at 7.0×10^{9} n cm^{-2} s^{-1} per cm to 3.90×10^{7} n cm^{-2} s^{-1} per cm when the channel is surrounded by 6 cm thick graphite which makes it very suitable for Large Sample Neutron Activation Analysis. The simulation agrees very well with the experimental k_{eff} of 1.00400 as compared with the final k_{eff} of 1.00390 recorded by this simulation.

1. Introduction

Determination of neutron flux in a research reactor is important in providing accurate activation analysis; present interest focusing on the use of Instrumental Neutron Activation Analysis (INAA). Studies show that neutron flux variation will occur in the irradiation channels as well as within the irradiation container (Bode et al., 1992; Jacimovic et al., 2003) thus knowledge of the neutron flux distribution in the irradiation channel and irradiation container is very important in determining the uncertainty obtained in use of k_0-INAA (Siong et al., 2008).

The type and strength of the neutron source and energy characteristics play an important role in any type of NAA including LSNAA, as the radioactivity produced is directly proportional to the neutron flux (φ) and energy-dependent neutron absorption cross section (σ). The neutron source should provide a sufficiently high neutron fluence rate so as to keep the product of neutron fluence rate and large test portion mass almost equal to that in small test portion NAA. This criterion indicates that for test portions with masses in the order of 2 kg a neutron fluence rate of approximately $5 \times 10^{12} \times 0.2/2000 = 5 \times 10^{8}$ cm^{-2} s^{-1} would result in an adequate induced radioactivity during the irradiation time, similar to that applied in conventional NAA in which a 200 mg test portion is processed. Fluence rates on the order of 10^{8}–10^{10} cm^{-2} s^{-1} are found at an extended distance from the core of small and medium-sized reactors (Beeley and Garrett, 1993) in beam tubes, and in thermal columns (TCs) (Bode and Overwater, 1993; Nair et al., 2003; Tzika et al., 2007). However, low fluence rates can also be realized – or even may be preferred – by lowering the reactor power because of fuel economy considerations (Bode, 2008; Gwodz, 2007).

In view of that modification and installation of the larger irradiation channel outside the reactor vessel would promote and enhance greater innovative utilization of neutrons produced by the reactor. This would greatly enhance performance of the research institution in the area of research and commercialization, and capacity building (Nyarko et al., 2011). Earlier works aiming to model GHARR-1 and its irradiation facilities to increase the utilization by design of epicadmium-shielded irradiation channel (Abrefah et al., 2010a); axial and radial distribution of thermal and epithermal neutron fluxes in the irradiation channels (Abrefah et al., 2010b) has been done. All these look at the existing irradiation channels in the reactor vessel and conventional NAA.

The purpose of this work is to improve the existing design of a Large Irradiation Channel at MNSR Facility in Ghana (Nyarko et al., 2011), by introducing a graphite medium around the irradiation site, serving as a reflector and a thermal medium, to increase the thermal neutron flux in the irradiation channel outside the reactor vessel. The objective of this work was to access the impact of the thermal column on the neutron flux distribution and gradient in the redesign slant tube of the reactor to enable Large Sample Neutron Activation Analysis (LSNAA).

In this paper, Monte Carlo N-Particle version 5 (MCNP-5) Code (X-5 Monte Carlo team, 2003) was employed in modelling this

* Corresponding author. Tel.: +233 0244869572.
E-mail address: matkasam@yahoo.com (M. Asamoah).

0306-4549/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.anucene.2011.11.019

new design. MCNP is a general-purpose, continuous-energy, generalized- geometry, time-dependent, coupled neutron/photon/electron Monte Carlo transport code, but only neutron was used. Monte Carlo refers to a statistical method wherein the expected characteristics of particles (e.g. particle flux) are estimated by sampling a large number of individual particle histories whose trajectories are simulated by a digital computer. After developing the new input deck, the program was run to find out the neutronic profile around the reactor vessel. The results obtained were analyzed to determine the neutron flux profile in the larger irradiation channel that will enable LSNAA using a low flux Miniature Neutron Source Reactor.

2. Materials and methods

From the neutronics analysis of the Ghana Research Reactor (GHARR-1) facility, neutron flux profile around the reactor vessel was determined and the highest neutron flux was recorded at three points around the vessel. At the third highest flux area, a large sample irradiation channel was modelled and series of neutronic analysis was performed and this was found to be feasible for Large Sample Instrumental Neutron Activation Analysis (LSINAA) (Nyarko et al., 2011). In this work, a similar irradiation channel with radius of 7.5 cm is modelled at a point around the reactor vessel where the neutron flux peaks, according to (Nyarko et al., 2011). A graphite column was introduced around the irradiation channel to increase the thermal neutron flux in the irradiation channel for LSINAA experiments.

The Monte Carlo N-Particle code, version 5 (X-5 Monte Carlo team, 2003) was used to simulate a fresh core for volume neutron flux in the modelled irradiation channel, assuming that reactivity loss due to fuel burnup and fission poisoning has been catered for by adding beryllium reflectors in the shim tray. The cylindrical tube was modelled at a point around the vessel as described in earlier work (Nyarko et al., 2011).

Similar cylinders of radius 2.96 cm were modelled along the diameter of the irradiation tube as shown in Fig. 1 of the MCNP visual editor print out. The total flux along the irradiation channel away from the reactor core was simulated. The model was simulated without graphite surrounding the irradiation channel and additional 5 models were simulated with graphite surrounding the irradiation channel with an increasing thickness of 1 cm.

Cells of 2.3 cm in height as shown in Fig. 2 of the MCNP virtual editor print out, were created along the height of the irradiation channel and simulated to monitor the axial flux profile along the height of the irradiation channel.

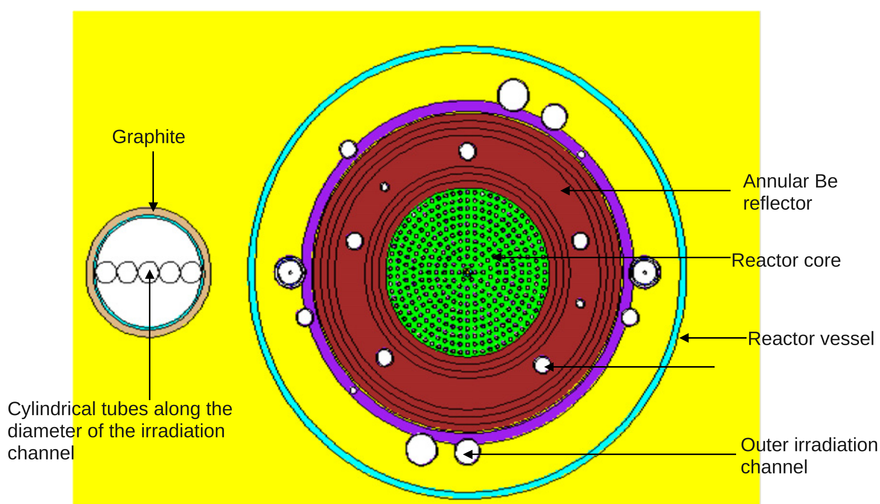

Fig. 1. MCNP visual editor print out showing cylindrical tubes along the diameter of the irradiation channel.

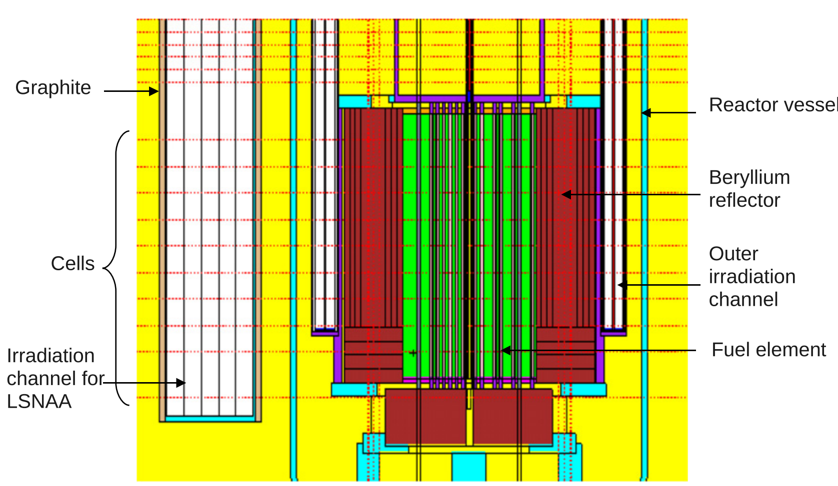

Fig. 2. MCNP visual editor print out showing the cells created along the height of the irradiation channel.