NUCLEAR POWER DEVELOPMENT AND NUCLEAR DATA ACTIVITIES IN MALAYSIA

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In this paper, research activities on nuclear power requirement carried out jointly by MINT and other organizations are described. Also discussed are activities on neutronics such as TRIGA reactor fuel management, storage pool criticality, and reactor fuel transfer cask calculations. In addition, recent work on radiation transport activities in MINT such as skyshine and photon phantom dose calculations using the MCNP and MRIPP computer codes are presented. Finally, nuclear data measurement works by researchers in Malaysian universities are described.

1. Introduction

A new nuclear era began in Malaysia with the establishment of the Tun Dr. Ismail Atomic Research Center (PUSPATI) in 1972. It was renamed the Nuclear Energy Unit (UTN) in June 1983 and then, the Malaysian Institute for Nuclear Technology Research (MINT) in August 1994. Initially, research activities in MINT were mostly involved the use our 1 MW(t) TRIGA Mark II reactor. The scope of research has widened considerably with the addition of more facilities such as the Gamma Irradiation Facility (SINAGAMA), Electron-Beam Machine (EBM) Facility, Radiation Vulcanization of Natural Rubber Latex (RVNRL) Facility, and Thermal Oxidation Plant (TOP).

In anticipation of increasing manpower requirement in the nuclear technology and nuclear power sectors, the Department of Nuclear Science was set up at the National University of Malaysia (UKM) in 1979. Nuclear related researches also intensified in other local universities.

This paper presents activities on nuclear power, neutronics, shielding, and radiation transport that are carried out in MINT. Nuclear data related works done at local universities are also discussed.

2. Nuclear Power Development

Concerned about over dependence on oil as the energy source for Malaysia, a feasibility study of generating electricity using nuclear power plant was carried out by NEB, the National Electricity Board (predecessor of Tenaga Nasional Berhad, TNB). The results indicated that commissioning of a medium-sized nuclear power plant was economically feasible around 1986/87[1]. However, with the discovery of more oil and natural gas, the nuclear power option was reassessed in late 1979[2]. The study that was carried out by NEB under an IAEA technical assistant project, recommended that the nuclear option should be kept as the last option and priority was to be given to the development of natural gas, coal, and hydro as the energy source.

In 1984-1985, another review on the nuclear power option, covering the period from 1985-2010 was conducted jointly by NEB and MINT (known as the Nuclear Energy Unit then) under an IAEA technical assistance project. The most optimistic scenario of the study expected that Malaysia would use electricity from nuclear power plant in the year 2005.[3]

Subsequently, several studies[4,5] related to nuclear power planning were carried from 1985 until 1989. These include the studies on the demand of energy and electricity, financial implication, manpower assessment, industrial capability assessment, uranium resources assessment, and nuclear power plant site selection survey. However, due to the low priority accorded to the nuclear power option, these studies were discontinued since 1989.

3. Neutronics

The objectives of reactor fuel management program at MINT is to ensure save and economic utilization of TRIGA reactor fuel. To this end, computer codes are used to simulate various core configurations before choosing the "best" fuel pattern for the core. The criteria for the fuel configuration are:- (1) the effective multiplication factor (k_{eff}) should be $1.03 \leq k_{eff} \leq 1.05$ and (2) the maximum power fraction of fuel element ≤ 1.6.

Initially, the SRAM[6] code developed at the Pennsylvania State University was modified for fuel management calculations. However, from 1990 onwards, TRIGAM[7], a modification of the TRIGAC code developed at Institute Josef Stefan, Ijubjana, was used for TRIGA reactor fuel management. The fuel data was obtained from the results of WIMS[8] calculations. At present, MINT TRIGA reactor is operating with core number 10 that will be replaced by core number 11 next year.

In the unlikely event that all of the fuel elements in the reactor core have to be transferred out of the core, a temporary fuel storage pool (1.5 m I.D. cylinder filled with water) is to be constructed to safely store all these fuel. The MCNP Monte Carlo code[9] is used to perform criticality calculations in the design of the fuel storage pool. Based on the limited space available in the reactor hall and the requirement that $k_{eff} \leq 0.8$, it is decided that the fuel should be stored in a square array with a lattice spacing of 7 cm. The 13 by 13 array can accommodate a total of 127 fuel elements while satisfying the above constraints. The fuel storage pool is one of the facilities to be constructed in the project to upgrade our reactor supporting facilities.

4. Radiation Transport

In order to use the fuel storage pool, a fuel element transfer cask is needed to transfer the fuel elements from the reactor tank to the fuel storage pool. The transfer cask design is done using computer codes such as ANISN[10], and ORIGEN[11]. The preliminary design is an annular cylinder with 4"-thick lead shield.

Skyshine radiation refers to radiation emanating from a source close to the ground into the atmosphere that get scattered by the air and arrive at a detector near the ground. Since the skyshine dose is normally very low, computational intensive calculations are needed in the analysis of skyshine problems. Hence, simplified methods such as the line-beam and conical-beam methods[12] have been developed for routine skyshine analysis and preliminary design of nuclear facilities.

Critical to the use of the line-beam and the conical-beam methods is the availability of the corresponding response functions. Line-beam and conical-beam response functions (LBRFs and CBRFs) for neutron and associated secondary photons have been evaluated by the author[13] using the MCNP code. These modern response functions are expressed in dose equivalent units based on ICRP recommendations[14,15] for three irradiation geometries:- effective dose equivalent for an anthropomorphic phantom [AP irradiation geometry], dose equivalent on the principal axis at a depth of 10 mm for radiation incident in the plane parallel beam [PAR] and isotropic irradiation geometries on the ICRU sphere [ISO]. These response functions are fitted with empirical formulas to facilitate their use in the line-beam and conical-beam methods. Correction for the effect of ground on the skyshine dose is effected through ground correction factors. These correction factors defined as the ratio of skyshine dose with air-ground interface to that of infinite-air medium, are evaluated from MCNP results. Empirical equations for these factors are tabulated[13].

Details of the evaluation of these response functions are described elsewhere[13]. The skyshine response functions are available from Radiation Shielding Information Center (RSIC), Oak Ridge National Laboratory (DLC-188/SKYDATA).

Figure 1 illustrates the result of applying the beam response functions to an open silo skyshine problem. In this problem, a point, isotropic, and mono-energetic source emitting neutrons of energy E (14 or 3.25 MeV) is placed 1 m below the top and on the axis of a cylindrical silo of 2-m inner radius.

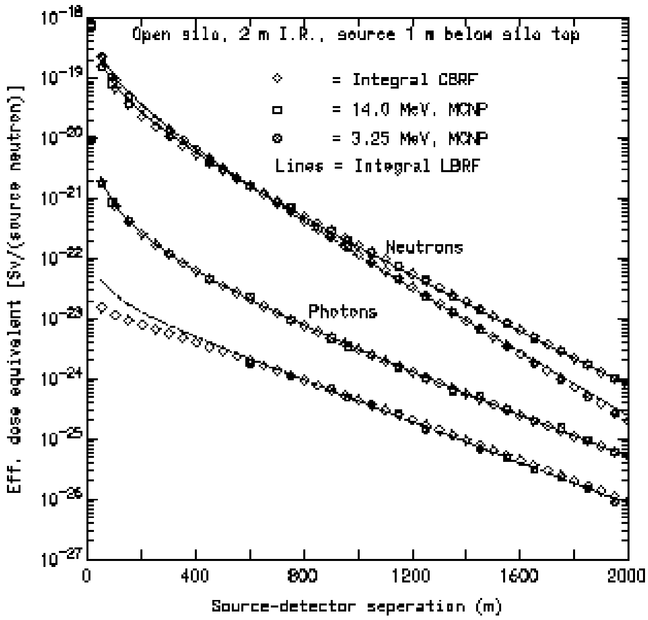

Figure 1: Integral line-beam and conical-beam method results for the open silo skyshine problem. Also shown are results calculated directly using the MCNP code.

The above response functions are for neutron source and detector both located at the same elevation. As an extension of the above work, the response functions for the source and detector located at different heights will be evaluated at MINT. Besides, the improvement of the response functions for low energy neutron source is also considered at MINT.

MINT is participating in a regional project coordinated by the International Atomic Energy Agency (IAEA)[16]. In this project the MRIPP computer code that is based on the MCNP code and the 3-D MRI geometry, is used to calculate the photon dose due to radioactive sources in the lung of the Asian Reference Man. The calculated results together with the measured results for the phantom that was on loan from the IAEA, will give the necessary calibration factors for internal dose assessments.

In another local institution of higher learning, a simple Monte Carlo code has been used to calculate the self-absorption correction for gamma ray counting of samples under different sample-detector geometries[17].

5. Nuclear Data Measurement

Nuclear and atomic data measurements are mainly performed in the universities. For example, the $^{10}B(n,t)2\alpha$ and $^{6}Li(n,t)\alpha$ reaction cross sections for neutron spectra in various TRIGA reactor irradiation facilities have been measured by researchers at UKM. The targets were irradiated in the Thermal Column, Rotary Rack, PAUS Delayed Neutron Analysis System, and the Central Thimble facilities of MINT TRIGA reactor.

Other activities carried out at UKM, in collaboration with Julich Research Center (KFA), include measurements of tritium atom production rates via ternary fission of UO_2 and ThO_2 and determination of the excitation functions of ^{9}Be(n,xt), ^{10}B(n,t)2α, and ^{14}N(n,t)^{12}C reactions. The ^{10}B(n,t)2α cross section for neutrons with energy range from 0.025 eV to 10.6 MeV and the ^{14}N(n,t)^{12}C cross section for neutron energy range of 5.0 to 10.6 MeV were also determined[18].

Experiments to measure the ^{241}Am-gamma photon scattered by low- to high-Z elements have been performed by the physics group at the University of Science Malaysia (USM). However, recent activities concentrate on measuring the gamma photon spectra back scattered by medium-Z elements such as Zn (Z=30), Mo (Z=42), and W (Z=74). Both the coherent and incoherent scattering of gamma photon are being investigated. Details of the measurements are given by Chong et al.[19]

6. Conclusions

Activities on nuclear power, neutronics, radiation transport, and nuclear data measurements carried out in Malaysia are presented. Unfortunately, the momentum to continue these activities have decreased greatly due to the low priority given to the nuclear power option and the difficulty of obtaining support for these works.

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