Source Term Evaluation for the TRIGA Mark-II Research Reactor of Bangladesh Using ORIGEN2.1 Code

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Abstract

The quantitative evaluation of the radionuclides inventories in nuclear reactors under routine and accidental conditions is one of the major topic in nuclear safety. The principal objective of this study is the evaluation of the radionuclides inventory and radioactive doses of important radionuclides, result from the routine operation of 3 MW TRIGA research reactor, Bangladesh. A systematic approach has been adopted to derive source term (ST) from the TRIGA research reactor. This derivation was made from the assessed inventory of peak radioisotope activities released in the core of the TRIGA research reactor by using isotope generation and depletion code ORIGEN2.1 for bornup of 800 MWD until end of December, 2016. Mass concentration of ^{235}U and ^{238}U, plutonium buildup, depletion of burnable poison ^{166}Er have also been characterized as a function of burnup. A total of 56 important radionuclides were considered and source term calculation was performed with the reactor original operational data which corresponds to average burnup of initial ^{235}U content of about 10% in the core and leads to total core inventory of 2.764E+18 Bq. Furthermore, a conservative estimation was also carried out to achieve 1200 MWD of burnup which corresponds to average burnup of initial ^{235}U content of about 15%.

Keywords: Source term, TRIGA, ORIGEN, radionuclide inventory, radioactive dose

1. Introduction

While many understandably feel that nuclear and radiation is unsafe yet there are too many myths that deviate from truth. It is common that nuclear and radiation are associated with danger, cancer and fatality. The radiation emitted from nuclear materials is invisible. It is however true that it can be measured and controlled. For any nuclear reactor, be it nuclear power reactor or nuclear research reactor, the source of radiation is the fuel itself. A fresh nuclear fuel emits no radiation and is inarguably safe. On the other hand, a spent fuel has different characteristic that it emits radiation with high energy originating from kinetic energy of fission products inside the fuel rod. Hence, safe management of spent fuel is highly crucial particularly at the end of the fuel cycle. As a nuclear fuel approaches its end of life cycle, the evaluation of the energy emitted by nuclides inside the reactor fuel is very important. In technical term, this is called radionuclides inventory analysis. The inventory analysis is required as it will be the basis for shielding calculation and waste characterization in particular for transportation, storage and disposal of the nuclear waste. Going back to the main productive source of fission products in reactor core, i.e. the fuel element, the amount of fission products existing at a given time during normal operation can be accurately estimated from the operation history of the core, as well as, the accompanying releases [1]. However, the fraction of fission products that will be released under a given set of circumstances (accidents) cannot be accurately estimated in an easy way. The release pathways go through the fuel matrix to fuel clad air interface, to primary coolant through clad crack, to secondary coolant through heat exchanger wall defects, to reactor containment, and finally to surrounding environment. The source term is the radionuclides generated in the fuel matrix due to fission process (radionuclides inventories in the fuel), it composes of actinides, fission products gases, and other radionuclides. The concentration of these nuclides depend on different factors such as fuel materials, operating power level, operating history, and fuel burnup [2].

The main purpose of this study is to determine the possible fission products from 3 MW TRIGA Mark-II research reactor core of the People's Republic of Bangladesh. Upon determining the routine releases in coolant, one may assess the efficiency of filtering systems, estimating the normal doses to workers, while examining if these limits fulfill the safety requirement imposed by regulatory body or not. The possible crack in fuel cladding material could be visualized. The source term was estimated here by using the isotope generation and depletion code ORIGEN2.1 developed by Oak Ridge National Laboratory (ORNL) [3]. ORIGEN2.1 was chosen in this purpose as it is extensively used in radionuclide inventory estimation in the reactor core, which is the source term. The code uses one-group cross-sections provided by neutron transport modeling program to calculate fuel depletion in time domain.

2. Reactor Description

The 3 MW TRIGA MARK II research reactor was commissioned at the Atomic Energy Research Establishment, Savar, Dhaka in 1986 and it went critical on 14th September, 1986. The reactor was designed to implement the various fields of basic nuclear research, manpower training and production of radioisotopes for its uses in agriculture, industry and medicine. The reactor is a light water cooled, graphite-reflected one, designed for continuous operation at a steady-state power level of 3000 kW (thermal). An outstanding feature of the TRIGA reactor

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