Nuclear Archaeology for CANDU Power Reactors

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The goal of this work is the development of so-called "nuclear archaeology" techniques to predict the irradiation history of both fuel-related and non-fuel-related materials irradiated in the CANDU (CANada Deuterium Uranium) family of nuclear reactors. In this application to CANDU-type reactors, two different scenarios for the collection of the appropriate data for use in these procedures will be assumed: the first scenario is the removal of the pressure tubes, calandria tubes, or fuel cladding and destructive analysis of the activation products contained in these structural materials; the second scenario is the nondestructive analysis (NDA) of the same hardware items via high-resolution gamma scans. There are obvious advantages and disadvantages for each approach; however, the NDA approach is the central focus of this work due to its simplicity and lack of invasiveness. The primary materials used in the structural components of CANDU reactors are various alloys of zirconium. For activation products of materials to be useful for prediction of reactor operating history, the activation product predictions must first be validated, and then their sensitivity to the desired reactor parameters must be established. Currently validation of activation products for CANDU reactors is not possible because measurement data are not available; therefore, studies in this report use simulated data with uncertainties to verify the techniques developed. The use of these techniques along with a previously developed inverse capability is expected to allow for the prediction of flux levels, burn time, and the total fluence for samples where the values of selected isotopes can be measured. A series of cases were evaluated for the activation of a common CANDU material, Zr-2.5Nb. The results are generally very good. Both the absolute and ratio cases reproduce the irradiation parameters when the decay time is specified. The dual nature of the Nb-94 and Nb-95/Zr-95 signatures should allow for a signal proportional to the sample total fluence to be obtained under practically any set of circumstances with a fairly simple NDA measurement. Tests using actual data from CANDU reactors are needed to verify this conclusion.