Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 562 (2006) 393–400
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Advanced foil activation techniques for the measurement of within-pin distributions of the $^{63}Cu(n,\gamma)^{64}Cu$ reaction rate in nuclear fuel

K. Macku[a,b,1], F. Jatuff[a], M.F. Murphy[a,*], O.P. Joneja[a,b], R. Bischofberger[c], R. Chawla[a,b]

[a] *Paul Scherrer Institute, Laboratory for Reactor Physics and System Behavior, CH-5232 Villigen-PSI, Switzerland*
[b] *Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland*
[c] *Applied Microswiss GmbH, CH-9471 Buchs, Switzerland*

Received 8 November 2005; received in revised form 8 February 2006; accepted 6 March 2006
Available online 29 March 2006

Abstract

Different foil activation techniques have been used for measuring spatial distributions of the $^{63}Cu(n,\gamma)^{64}Cu$ reaction within two pins of a SVEA-96 Optima2 boiling water reactor fuel assembly, at the critical facility PROTEUS. This reaction is of interest because its 1/v cross-section gives it a good representation of the ^{235}U fission rate. Initially, radial capture rate profiles were measured with mechanically punched copper foils. More detailed profiles were then determined by using a 0.2 mm copper wire spiral (~200 μm resolution), as well as 5-, 10-, and 20-ring UV-lithography, electroplating, and molding (UV-LIGA) foils (up to a 100 μm resolution). For azimuthal measurements, apart from manually cut activation foils (into 8 sectors), 8- and 12-sector LIGA foils were used. The highly versatile LIGA foils have the additional advantage of being very easily separated into individual pieces after irradiation without the use of punches or other cutting tools. In order to account for the invasive character of the foil activation techniques, corrections to account for sample perturbations and for self-shielding effects were determined via simplified Monte Carlo (MCNP4C) modeling of the experimental setup. The final results from the various measurements of $^{63}Cu(n,\gamma)^{64}Cu$ within-pin distributions have been compared with MCNP computations employing a detailed model of the full SVEA Optima2 fuel assembly.

PACS: 25.85.Ec; 28.20.Fc; 28.20.Gd; 28.50.Dr

Keywords: BWR fuel; Activation foils; Fission in ^{235}U; Within-pin reaction rate distributions; LIGA

1. Introduction

Light water reactors (LWR) represent more than 80% of all nuclear reactors in the world [1]; they dominate the nuclear energy scene largely because their core and fuel assembly designs have evolved significantly over time, in order to meet more stringent economic and safety demands. The increase in the complexity of LWR fuel assemblies has been particularly pronounced in the case of boiling water reactors (BWRs).

The design of modern BWR assemblies is governed by general nuclear power plant (NPP) requirements such as safe and reliable performance, optimal fuel utilization (implying increased burnup and cycle lengths), and a high degree of flexibility in NPP operation. These requirements are fulfilled in current fuel assembly designs through the usage, for example, of increased average enrichments, high gadolinium loadings and part-length fuel pins. Such features, in neutronic terms, lead to very heterogeneous assemblies not only causing variations in the power density of individual fuel pins, but also strong radial and azimuthal gradients in reaction rate distributions within the pins themselves.

As the fuel assembly complexity increases, more sophisticated modeling capabilities are required for the adequate prediction of operational and safety parameters.

*Corresponding author. Tel.: +41563102891; fax: +41563104527.
E-mail address: mike.murphy@psi.ch (M.F. Murphy).
[1]Present address: Swiss Nuclear Safety Inspectorate, CH-5232 Villigen-HSK, Switzerland.

0168-9002/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2006.03.004