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TRIGA FUEL ELEMENT BURNUP DETERMINATION BY MEASUREMENT AND CALCULATION

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Introduction

This analysis of fuel element burnup was done for the spent fuel element shipment to the United States for final disposal [1] and within the scope of the TRIGA benchmark project [2] accepted by the International Criticality Safety Benchmark Evaluation Project (ICSBEP) working group. However, the results are acceptable to all TRIGA fuel element burnup calculations. Since experimental methods, even nondestructive gamma scanning, are normally too complicated for determining burnup of large numbers of fuel elements, reactor calculations are the most common and practical method for fuel element burnup determination. Good knowledge of calculated fuel element burnup accuracy is also needed for correct interpretations of all research reactor experiments, when spent fuel elements are present in the reactor core.

Methods

The most commonly used methods for non-destructive fuel element burn-up determination at research reactors are reactor calculations, reactivity measurements and gamma ray spectrometry. Reactor calculations are normally used for continual monitoring of the fuel element burn-up history because they are easy to apply and do not influence reactor operation. However, their accuracy was sometimes questionable, particularly in cases of complicated mixed cores and mixed rings, when a one dimensional model was used.

To estimate the accuracy of the fuel element burnup calculation different factors influencing the calculation were studied. To cover different aspects of burnup calculations, two in-house developed computer codes were used in calculations. The first (TRIGAP) is based on a one-dimensional two-group diffusion approximation, and the second (TRIGLAV) is based on a two-dimensional four-group diffusion equation. Both codes use WIMSD program with different libraries for unit-cell cross section data calculation. The burnup accumulated during the operating history of the TRIGA reactor at «Johef Stefan» Institute was calculated for all fuel elements [3]. Elements used in the core during this period were standard SS 8.5% fuel elements, standard SS 12% fuel elements and highly enriched FLIP fuel elements. During the considerable period of operational history, FLIP and standard fuel elements were used simultaneously in mixed cores.

The accuracy of the calculations was estimated also by comparing the calculated results to the results of the experiments. Fuel element burnup was measured by the reactivity method [4]. The reactivity method is based on the assumption that the reactivity worth of the fuel element is a known function of burnup. For the measurements we established a practically critical core configuration with fuel elements to be measured at the selected measurement position. The digital reactivity meter was used to measure core excess reactivity. Comparison shows agreement within ±1 burned ^{235}U burnup for most of the fuel elements. Discrepancies for some fuel elements, which were positioned near transient control rod air-follower, could be explained with poor fuel element surrounding descriptions in the unit-cell calculation.

Conclusions

The results show that fuel element burnup estimates can be significantly wrong if one uses calculation models that are too simplified. The error can be over 50% in mixed cores containing low and highly enriched fuel elements. The effect of new WIMSD library on burnup calculations is not so pronounced. Results of experiments showed that one of the largest uncertainties of the calculated burnup arise from inaccurately known fresh fuel composition and from rather large inaccuracies in reactor thermal power calibration.

References

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