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#07-206 Safeguards investigations based on gamma spectrometry to determine the activity ratio of fission products in spent fuel assemblies of VVER-440 Nuclear Reactor

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Safeguards investigations deal with the inspection of fission materials and their goal requires a reliable experimental verification method to determine the power history of spent fuels. In nuclear power plants it is a key task to continuously monitor the fuel burnup, for this purpose different types of verified deterministic and stochastic codes are applied. For both tasks, it is absolutely necessary to validate experimentally the theoretical models and calculations, for which one of the most appropriate methods is in-situ gamma spectrometry.

High resolution gamma spectrometry measurements have been carried out on the VVER-440 type spent fuel assemblies of Paks Nuclear Power Plant, Hungary. The purpose of the measurements was to verify the final burnup values calculated by the method of the power plant's staff. Until now, gamma spectra of more than 100 fuel assemblies were collected and analysed by using coaxial high-purity germanium semiconductor detectors. The majority of the measured spent fuel are so called work assemblies, but few of the absorber follower assemblies were also measured. The measured assemblies have varying initial enrichments (1.6 –4.7%), cooling times (1 –5 y) and operational histories, the latter resulting in differing levels of burnup. All of the hexagonal assemblies were measured from either all six or three non-neighbouring sides, which means that some information regarding the whole assembly can be derived. Additionally, the data collected throughout the years can be used for safeguards method investigation and development as well.

Due to the measurement conditions and the relatively short cooling times, only prominent gamma emitting fission products are able to be measured. However, since the production of these isotopes depends solely on the fuel's initial composition, geometry and operational parameters, their final activity is connected to the relevant safeguards quantities, namely the burnup, initial enrichment and cooling time. By using high resolution gamma spectrometry, we were able to detect the 137Cs, 134Cs, 154Eu, 106Ru, 144Ce, 125Sb, 110mAg, 95Zr, 103Ru and 91Y fission products. The last three isotopes could only be measured in assemblies with cooling times shorter than two years, due to their short half-lives. The difficulties raised by an absolute calibration procedure limit us, at the present, to use a relative efficiency calibration method. With such a "self-calibration" technique, only activities relative to some other isotope can be calculated.

In the present study, we examine our dataset to reveal connections between the measured activity ratios and the three relevant quantities by utilizing model functions, dependent on the burnup, initial enrichment and cooling time, and statistical methods such as cluster analysis. The clustering of certain isotopic activity ratios shows at a glance which assemblies have similar or dissimilar initial compositions and operating histories. We also investigate the axial distribution of fission product activity ratios from assemblies measured in several different axial positions. From this, we can determine the burnup level seen by the detector at a given axial position of the fuel and compare that to the known average assembly burnup.

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