**Stress on Cladding Imposed by the Matrix Swelling from Alpha Irradiation in High Burnup Spent Nuclear Fuel**

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ABSTRACT

During long-term storage of spent nuclear fuel (SNF), the $UO_2$ matrix may undergo swelling due to alpha particles decays producing helium in the matrix (Rondinella, et al., 2010). If the gap between cladding and the matrix is nearly closed as may occur for high burnup SNF (e.g., ~ 60 GWd/MTU [37 M BTU d/lb]), this additional matrix swelling may impose a stress on the cladding. If this stress is sufficiently high it may impact cladding integrity. This paper evaluates the potential for matrix swelling and gap closure in high burnup SNF. Critical test methods, data validity, and uncertainty of data and models are discussed. The size of the gap is evaluated at the end of irradiation after cooldown in the pool and heat-up in dry storage to determine the time when the stress would be applied to the cladding.

The duration of storage is postulated for several hundred of years. This has been simulated in short-term laboratory tests using high levels of alpha radiation on unirradiated $UO_2$ by a number of authors. The uncertainties associated with high radiation and rate effects (i.e., time effect) were studied with annealing kinetics of the swelling. The data from the various sources were compared to establish the uncertainty in the swelling rate. Depending on the procedure adopted to apply an alpha radiation, some data showed saturation of swelling with time while others did not. The extrapolation to the long term swelling of SNF from the accelerated test samples was made based on displacement per atom (dpa) as a function of time. For various dpa values, actual swelling (i.e., lattice parameter increase) was measured for test samples, not for aged SNF.

Systematic post irradiation examination (PIE) data on gap closure, including the effects associated with the burnup distribution along the axis of a SNF rod, are limited so the gap-closure of high burnup SNF as it comes from the reactor is mainly based on fuel code calculations, based on data from reactor operation (FRAPCON, Geelhood, et al., 2011, NRC). The gap to be closed by the SNF swelling during storage was calculated taking into account the differential thermal properties of thermal expansion in the irradiated fuel (i.e., SNF) and cladding along with the temperature distribution experienced by the SNF in storage.

Based on the uncertainties in the extent and time of gap closure and the uncertainties in the rate of swelling, the potential for stress being placed on the cladding during the first 300 years of storage have been estimated. Future experiments may be conducted to confirm the presence and magnitude of the stress.

References:

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