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BRITTLE FAILURE OF SPENT FUEL CLADDINGS UNDER LONG-TERM DRY INTERIM STORAGE CONDITIONS –PRELIMINARY ANALYSIS

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The evaluation of cladding integrity is a major issue to be demonstrated in Germany for extended interim storage periods up to 100 years and subsequent transportation considering operational and accidental conditions with respect to reactor operation, cask drying and dry interim storage. The chemical reaction between the zirconium fuel cladding and the cooling water in water-cooled reactors produces hydrogen and zirconium oxide. Hydrogen diffuses into the cladding and precipitates as zirconium hydrides when the solubility limit is reached, preferably oriented in hoop direction. At high temperatures during vacuum drying procedures, the hydrides can dissolve. Over a succeeding period of slow cooling with existing hoop stress the hydrides precipitate again, but partly reoriented along the radial direction of the cladding. This change of microstructure in combination with a decreasing temperature (0.5…2 K/year) during (extended) interim storage and additional mechanical load by handling procedures or under accident conditions could lead to a potential cladding embrittlement and consequently increased failure probability. The current research project BRUZL (Fracture mechanical analysis of spent fuel claddings during long-term dry interim storage) has been launched by BAM to investigate potential spontaneous brittle failure of spent fuel claddings at small deformation under long-term dry interim storage conditions. Based on the key thesis that radial hydrides may be considered as sharp cracks, BAM plans Ring Compression Tests (RCT) with unirradiated cladding samples with representative hydride distribution (including hydride reorientation), numerical simulation of the RCT, calculation of fracture toughness, and identification of failure criteria. Without hydride reorientation, samples under RCT conditions show large plastic deformation with gradually decreasing force at the end of the test indicating ductile failure. Contrary, with hydride reorientation, spontaneous failure with abruptly decreasing force at very small deformation and low temperature is possible dependent on hydrogen content and mechanical load during hydride reorientation.

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