APPENDIX 8B FUEL CLADDING CREEP

Creep is the dominant mechanism for cladding deformation under normal conditions of storage. The relatively high temperatures, differential pressures, and corresponding hoop stress on the cladding will result in permanent creep deformation of the cladding over time. Several laboratory programs have demonstrated that spent nuclear fuel (SNF) has significant creep capacity even after 15 years of dry storage. NUREG/CR-6831, "“Examination of Spent Fuel Rods After 15 Years in Dry Storage,” issued September 2003, reported that irradiated Surry-2 pressurized-water reactor (PWR) fuel rods (35.7 gigawatt days per metric ton of uranium (GWd/MTU)) that were stored for 15 years at an initial temperature of 350 degrees Celsius (°C) (662 degrees Fahrenheit (°F)) (with temperatures reaching as high as 415 °C (779 °F) for up to 72 hours) experienced thermal creep, which was estimated to be less than 0.1 percent. Post-storage creep tests were conducted to assess the residual creep capacity of the Surry-2 fuel rods. One rod segment experienced a creep strain of 0.92 percent without rupture at 380 °C (716 °F) and 220 megapascals (MPa) in 1,820 hours (75.8 days). A different rod segment was tested at 400 °C (752 °F) and 190 MPa for 1,873 hours (78 days), followed by 693 hours (28.9 days) at 400 °C and 250 MPa, and experienced a creep strain of more than 5 percent without failure (Tsai et al. 2006). Profilometry measurements on that fuel rod indicated that the creep deformation was uniform around the circumference of the cladding with no signs of localized bulging, which can be a precursor for rupture. A report of the literature (Beyer 2001) also indicates that some SNF cladding can accommodate creep strains of 2.8—7.5 percent at temperatures between 390 and 420 °C and hoop stresses between 225 and 390 MPa. Other significant contributions to the understanding of the effects of creep on SNF cladding can be found in several references (Einziger et al. 1982; Rashid et al. 2000; Hendricks 2001; Rashid and Dunham 2001; Machiels 2002). In general, these data and analyses support the conclusions that (1) deformation caused by creep will proceed slowly over time and will decrease the rod pressure, (2) the decreasing cladding temperature also decreases the hoop stress, and this too will slow the creep rate so that during later stages of dry storage, further creep deformation will become exceedingly small, and (3) in the unlikely event that a breach of the cladding from creep occurs, it is believed that this will not result in gross rupture.

Based on these conclusions, the staff has reasonable assurance that creep under normal conditions of storage will not cause gross rupture of the cladding and that the geometric configuration of the SNF will be preserved, provided that the maximum cladding temperature does not exceed 400 °C (752 °F).

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