NE 533 Exam #3

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① $T = 625\,K$ $t = 400\,d$ $\Delta = 500\,\mu m$

a) est oxide thickness

$$t^*(d) = 6.62 \times 10^{-7} \exp \frac{11949}{T} = 133 \text{ days}$$

sample is past transition

$$\delta^* (\mu m) = 5.1 \exp \frac{-550}{T} = 2.115\,\mu m$$

$$K_L \left(\frac{\mu m}{d}\right) = 7.48 \times 10^6 \exp \frac{-12500}{T} = 0.0154$$

$$\delta(\mu m) = \delta^* + K_L (t - t^*)$$

$$= 2.115 + 0.0154 * (400 - 133) = \boxed{6.23\,\mu m}$$

b) $f_{pu} = 18\%$ $PBR = 1.56$ $\rho_{Zr} = 6.5\,g/cc$

$\rho_{ZrO_2} = 5.68\,g/cc$

$$C_H = \frac{2 f \times \delta \times \rho_{oxide} \times f^{O}_{ZrO_2} \times \overset{=1}{M_H} / \overset{=16}{M_O}}{\left(t - \frac{\delta}{PBR}\right) \times \rho_{metal}}$$

$$f^{O}_{ZrO_2} = \frac{16 \times 2}{16 \times 2 + 41} = 0.26$$

$$C_H = \frac{2(0.18)(6.23\,\mu m)(5.68\,\frac{g}{cm^3})(0.26)\left(\frac{1}{16}\right)}{\left(400 - \frac{6.23}{1.56}\right) \times 6.5\,\frac{g}{cm^3}} \times 10^6$$

$$= \frac{0.207}{2474.04} \times 10^6 = \boxed{80.42 \text{ wt ppm}}$$

② $\alpha_{th} = 11 \times 10^{-6}$ $f_{rate} = 3.5 \times 10^{13}$ fis/cm^3 s

$T = 1200k$ $T_{ref} = 300k$ $\Delta\rho_0 = 0.01$ $B_D = 5 \frac{MWD}{kgU}$

$\rho(UO_2) = 10.97$ g/cc $t = 85$ days $= 0.0053$ FIMA

Δ in fuel vol

$$\varepsilon_{tot} = \varepsilon_{th} + \varepsilon_D + \varepsilon_{SFP} + \varepsilon_{GFP}$$

$$\varepsilon_{th} = \alpha \Delta T = 11 \times 10^{-6} (1200 - 300) = 0.0099$$

$$\varepsilon_D = \Delta\rho_0 \left[\exp\left(\frac{B \ln 0.01}{C_D B_D} \right) - 1 \right] \quad C_D = 1 \; > 750°C$$

$$B = 3.5E13 \times 3600 \times 24 \times 85 / 2.45e22$$

$$= 0.01049$$

$$\varepsilon_D = -0.0079$$

④ Soluble oxides; insoluble oxides; metals; volatiles; & noble gases

⑤ Micro-structure based fuel performance modeling one based on the current state of the evolving fuel microstructure instead of burn-up. It takes into account how changes of the microstructure of the fuel affect fuel properties + thus fuel performance. It has the potential to provide more predictive fuel performance capabilities.

⑥ Low neutron cross section; corrosion resistance in high temperature water; resistance to void swelling

⑦ Metallic fuels such as U-Zr exhibit fuel redistribution because the alloying metal (in this case, Zr) diffuses up the temperature gradient and has different solubilities in each phase of U.

⑧ MOX fuel is typically operated at a much higher linear heat generation rate than typical LWR fuel + has higher power density + heat flux than typical LWR fuel. MOX fuels are also typically designed to achieve high burnup compared to LWR fuel.

(9) Corrosive Environment: interaction b/t clad + fuel introduces a more corrosive environment to clad

Susceptible material: Zirconium alloy cladding is prone to PCI failure, which increases its interaction w/ the fuel + increases susceptibility to SCC failure.

Sufficient stress: PCI increases the stress on the cladding because the swelling fuel is now in contact w/ the clad + exerts force on the clad.

Sufficient Time: The longer a fuel rod is in an operating reactor undergoing PCI, the more time there is available for the SCC to form + propagate, eventually leading to cladding failure.

(10) Pulverization of fuel in a HBS is hypothesized to be caused during a LOCA when trapped gas heats up + overpressurized + initiates cracking at these overpressurized bubbles. Scientists are currently working to simulate pulverization + are working to validate pulverization criteria by comparing w/ existing experimental data.

(11) RIA causes a fast rise in fuel power + temperature, leading to fuel rod failure + release of radioactive materials into the coolant causing rapid steam generation + pressure pulses. LOCA results in an increase in temperature + decrease in coolant pressure + can lead to cladding ballooning + rupturing. An example of a RIA is a control rod ejection.

(12) Two of the pathways to improve the accident tolerance of fuel include: (1) improved cladding properties such as improving resilience to clad fracture + higher melt temperatures; and (2) improved fuel properties such as lower operating temperatures + higher fuel melt temperatures. Current ATF options being pursued to improve cladding resilience to fracture + corrosion is cladding coatings.

(13) pellet-clad mechanical interaction + dryout from nucleate boiling