85/100

Hunter Thompson NucE 497 Exam 2

-5, 20/25

1\. 1. Reactor startup. As temperature rapidly increases, fuel experiences thermal expansion and fracturing. As a result, fuel densification occurs. Fuel expansion thins the gap. Cracking lowers thermal conductivity, increasing fuel temperature.

2\. Point defect diffusion, fission gas segregation. Average grain size begins to increase, less grains throughout the pellet. Point defects cluster. Fuel densification causes gap to temporarily widen.

-1, Gap widening increases T

3\. Fission product swelling & fission gas release. Cladding experiences irradiation growth. Grain size continues to increase. Cladding embrittlement due to irradiation hardening. Stress corrosion cracking in clad. Because of swelling, gap gets thinner.

4\. Fuel expansion leads to PCMI. (This can be infered, as the gap width is now zero). Cladding corrosion. Fuel & clad both experience creep. Cladding embrittlement due to irradiation hardening. Bonding between pellet & clad (PCCI). PCCI caused jump in heat transfer (seen in plot 1)

-2, Gas release causes bump in T as swelling continues

5\. Temperature increses further. Cladding may crack due to pressure caused by PCMI. Gas released by grain growth.

-2, T increases due to fuel conductivity decreasing with burnup

-4, 26/30

2. $a = 8\mu m$ $\quad \phi = 2.0\times10^{13}$ $\quad T = 900°C = 1173.15\ K$

a) $D = D_1 + D_2 + D_3$

$$D_1 = 7.6\times10^{-6} e^{-\frac{3.03}{K_bT}} = 7.6\times10^{-6} e^{-\frac{3.03}{(8.6173303\times10^{-5})(1173.15)}} = 7.313\times10^{-19}$$

$$D_2 = 1.41\times10^{-18} e^{-\frac{1.19}{K_bT}} \sqrt{\dot{F}} \qquad \dot{F} = q N_f \sigma_f \phi \qquad \sigma_f = 5.5\times10^{-22}$$

$\underline{\text{Assuming } q = 0.042 \text{ and } N_f = 1.03\times10^{21}}$ $\rightarrow \dot{F} = 4.7586\times10^{11} \rightarrow D_2 = 7.513\times10^{-18}$

Homework 4

-0, Fdot = 2e13

$$D_3 = 2.0\times10^{-30}\dot{F} \qquad D_3 = 9.5172\times10^{-19}$$

$$D_1 + D_2 + D_3 = D \quad \boxed{D = 9.19602\times10^{-18}\ cm^2/s}$$

b) $N_{gas} = y\dot{F}t V_{fuel}$ $\quad$ * $\underline{\text{Assuming } V_{fuel} = 0.000006284\ m^3 \text{ (Homework 4)}}$ *

$$N_{gas} = 0.3017(4.7586\times10^{11})(63072000s)(0.000006284\ m^3)$$

-0, Fdot = 2e13

N_{gas} Produced $= 5.6902\times10^{13}$ atoms

$$f_{in\text{-}pile} = 4\sqrt{\frac{Dt}{\pi a^2}} - \frac{3}{2}\frac{Dt}{a^2} \qquad f = 4\sqrt{\frac{9.19602\times10^{-18}(63072000)}{\pi(0.0008\ cm)^2}} - \frac{3}{2}\frac{(9.19602\times10^{-18})(63072000)}{(0.0008)^2}$$

$$= 0.067938088 - 0.0013594 = 0.066579$$

$$N_{released} = N_{gas}(f) \qquad \boxed{N_{released} = 3.7885\times10^{12}\ atoms}$$

c) $f_{out\text{-}of\text{-}pile} = 6\sqrt{\frac{Dt}{\pi a^2}} - 3\frac{Dt}{a^2}$ $\quad | \quad N_{gas\text{-}in\text{-}fuel} = 5.6902\times10^{13} - 3.7885\times10^{12} = 5.31185\times10^{13}$

$$0.1(N_{gas\text{-}in\text{-}fuel}) = \boxed{N_{gas\text{-}released} = 5.3135\times10^{12}\ atoms}$$

$$f = \frac{5.3135\times10^{12}}{5.31185\times10^{13}} = 0.1\ ✓ \qquad 0.1 = 6\sqrt{\frac{9.19602\times10^{-18}t}{\pi(0.0008)^2}} - 3\frac{9.19602\times10^{-18}t}{(0.0008)^2} \qquad \boxed{t = 6.4138\times10^{7}s}$$

-4, Recalculate D at new T = 2273 K

-6, 24/30

3. $T = 600K$, $t = 31536000\,s = 365\,d$, $t_c = 0.6\,mm$

a) $\delta^* = 5.1\,e^{-\frac{550}{600}} = 2.039\,\mu m$ | $t^* = 6.62\times10^{-7}\,e^{\frac{11949}{600}} = 295\,d$

$K_L = 7.48\times10^{6}\,e^{\frac{-12500}{600}} = 0.00670$ | $\delta = \delta^* + K_L(365d - 295d) = 2.5080\,\mu m$

$\delta(\mu m) = \frac{W\left[\frac{mg}{dm^2}\right]}{14.7}$ $\quad 2.5080 = \frac{W}{14.7}$ $\quad \boxed{W = 36.87\ {}^{mg}/_{dm^2}}$

-2, Metal lost = oxide thickness/1.56
-2, ZIRLO thickness is lost, not gained

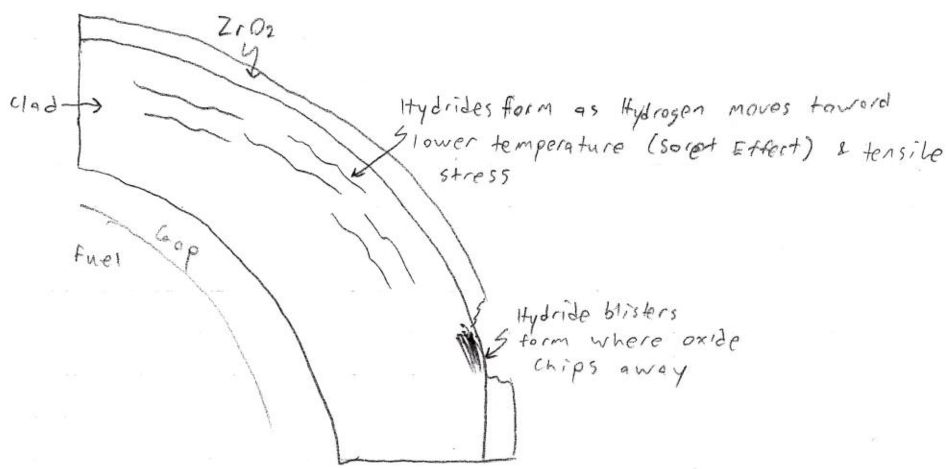
b) $\delta = 2.5080\,\mu m$

$\delta + t_c = 0.002508\,mm + 0.6\,mm = \boxed{0.602508\,mm}$

c) $C_H^{clad} = \frac{2 f \delta \rho_{oxide} f^0_{ZrO_2} \frac{M_H}{M_O}}{(t - \frac{\delta}{PBR})\rho_{Zr}} \times 10^6 = \frac{2(0.15)(2.508\,\mu m)(0.26)\frac{1}{16}}{(602.508\,\mu m - \frac{2.508}{1.56})6.59/cm^3} \times 10^6 = \frac{12226.5}{3905.857} = \boxed{3.13\ wt.ppm}$

-2, Should be original thickness

d)



-0, 15/15

4. a)

LOCA	RIA
- Reduction or elimination of coolant flow	- Rapid insertion of positive reactivity
- Lowers reactor pressure coolant	- Causes rapid increase in fuel temperature
- Fuel temperature increases due to decay heat	- Leads to Pellet Clad Mechanical Interaction
	- Increases temperature in cladding
- without external pressure, internal clad pressure may cause ballooning	- Increases gas & mechanical pressure on clad

b) Both RIA and LOCA see the fuel experience temperature increase. Because of internal pressure from gas & PCMI, both accidents can cause ballooning & rupture of the cladding

c) Fuel additives, such as SiC, BeO, & Nano-diamond increase the thermal conductivity of UO_2 fuel, lowering the internal fuel temperature, fission product release, & thermal stress. These benefits assist the main goal of the program (to give engineers more time to cope with potential accidents) by widening the window of time before significant, temperature-dependant failures (fuel melt, clad burst) can occur in a LOCA or RIA accident. These additives would be compatible with current reactor designs, fit the current fuel cycle, & would only be slightly more expensive to produce.