Tyler Steiner

Your exam is very similar to four other students and I suspect cheating, 0/100

Problem 1

-2, 23/25

1. Cladding: no effect — constant temp

   Gap: quick change due to thermal expansion — sharp drop in gap width

   Fuel: thermal expansion — spike in fuel temperature

2. Cladding: no effect — constant temp

   Gap: grows due to densification — increase in gap width

   Fuel: densification and point defects — increase in gap width

3. Cladding: no effect — constant temp

   Gap: returns to shrinking as fuel expands — decreasing gap width

   Fuel: movement of impurities such as, fission gas moving to grain boundaries and voids — declining temp

4. Cladding: creep — approaching 0 gap width

   Gap: continues to shrink — decreasing gap width

   Fuel: creep and fission gas release — hump in temperature plot

5. Cladding: interact with fuel — 0 gap width

   Gap: closed — 0 gap width

   Fuel: interact with cladding and increase temprerature — 0 gap width and increasing temp

-2, T increases due to additional drop in fuel conductivity with burnup

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Problem 2

-2, 28/30

$a = 8\,\mu m = .0008\,cm$

$\dot{F} = 2 \times 10^{13}\ \frac{fissions}{cm^3\ s}$

$T = 900°C = 1173\,K$

a) $D = D_1 + D_2 + D_3\ \frac{cm^2}{s}$

$k_b = 8.6173 \times 10^{-5}\ \frac{eV}{K}$

$D_1 = 7.6 \times 10^{-6}\ e^{-3.03\,eV/k_bT}$

$= 7.6 \times 10^{-6}\ e^{-3.03/(8.6173\times10^{-5})(1173)}$

$= 7.28 \times 10^{-19}\ \frac{cm^2}{s}$

$D_2 = 1.41 \times 10^{-18}\ e^{-1.19\,eV/k_bT}\sqrt{\dot{F}}$

$= 1.41 \times 10^{-18}\ e^{-1.19/(8.6173\times10^{-5})(1173)}\sqrt{2\times10^{13}}$

$= 4.86 \times 10^{-17}\ \frac{cm^2}{s}$

$D_3 = 2 \times 10^{-30}\ \dot{F}$

$= 2\times10^{-30}(2\times10^{13})$

$= 4\times10^{-17}\ \frac{cm^2}{s}$

$$\boxed{D = 8.94 \times 10^{-17}\ \frac{cm^2}{s}}$$

b) $N_{fg} = y\dot{F}t$

$= (.3017)(2\times10^{13})(63072000\ s)$

$= 3.81 \times 10^{20}\ \frac{atoms}{cm^3}$

-2, Wrong eqn (check tau)

$N_{rel} = f N_{fg}$

$f = 1 - \frac{6}{\pi^2} e^{-\pi^2 Dt/a^2}$

$= 1 - \frac{6}{\pi^2} e^{-\pi^2(8.94\times10^{-17})(63072000)/(.0008)^2}$

$= .4427$

$$\boxed{N_{rel} = 1.68 \times 10^{20}\ \frac{atoms}{cm^3}}$$

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Problem 2 (continued)

c) $f = .1$

$T = 2000°C = 2273\ K$

$D = D_1 + D_2 + D_3 \quad \frac{cm^2}{s}$

$k_b = 8.6173 \times 10^{-5} \frac{eV}{K}$

$D_1 = 7.6 \times 10^{-6}\, e^{-3.03 eV / k_b T}$

$= 7.6 \times 10^{-6}\, e^{-3.03 / (8.6173 \times 10^{-5})(2273)}$

$= 1.45 \times 10^{-12} \frac{cm^2}{s}$

$D_2 = 1.41 \times 10^{-18}\, e^{-1.14 eV / k_b T} \sqrt{\dot{f}}$

$= 1.41 \times 10^{-18}\, e^{-1.14 / (8.6173 \times 10^{-5})(2273)} \sqrt{2 \times 10^{13}}$

$= 1.449 \times 10^{-14} \frac{cm^2}{s}$

check this $\dot{f}$ if time allows *

$D_3 = (2 \times 10^{-30})(\dot{f})$

$= (2 \times 10^{-30})(2 \times 10^{13})$

$= 4 \times 10^{-17} \frac{cm^2}{s}$

$D = 1.469 \times 10^{-12} \frac{cm^2}{s}$

$f = 6\sqrt{\frac{Dt}{\pi a^2}} - \frac{3Dt}{a^2}$

$.1 = 6\sqrt{\frac{(1.469 \times 10^{-12})t}{\pi (.0008)^2}} - \frac{3(1.469 \times 10^{-12})t}{(.0008)^2}$

$\boxed{t = 401.51\, s}$

$N_{rem} = N_{fg} - N_{rel}$

$= 3.81 \times 10^{20} - 1.68 \times 10^{20}$

$= 2.12 \times 10^{20}$

$N_{rel_2} = N_{rem}\, f$

$= (2.12 \times 10^{20})(.1)$

$\boxed{= 2.12 \times 10^{19} \frac{atoms}{cm^3}}$

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Problem 3

-6, 24/30

ZIRLO

T: 600 K

t: 1yr

t_0: .6 mm

a) $t^* = 6.62\times10^{-7}\, e^{11949/T}$

$= 6.62\times10^{-7}\, e^{11949/600}$

$= 295$ days

$\delta^* = 5.1\, e^{-550/T}$

$= 5.1\, e^{-550/600}$

$= 2.039$ um

$\delta = \delta^* + k_L\,(t - t^*)$

$k_L = 7.48\times10^{6}\, e^{-12500/T}$

$= 7.48\times10^{6}\, e^{-12500/600}$

$= 6.7\times10^{-3}$

$\delta = (2.039\,\text{um}) + 6.7\times10^{-3}(365 - 295)$

$= 2.51$ um

$\delta = w/14.7$

$2.51 = w/14.7$

$\boxed{w = 36.87\ \frac{mg}{dm^2}}$

b) $t_2 = t_0 + \delta$

$= .6\text{mm} + 2.51\,\text{um}$

$\boxed{= 602.51\,\text{um}}$

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

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Problem 3 (continued)

c) $f = .15$

$t = 1\,yr$

$$N_o = \frac{w N_a}{M_o}$$

$$= \frac{(36.87\times10^{-3})(6.02\times10^{23})}{16}$$

$$= 1.387\times10^{21}\ \frac{\text{atoms O}}{dm^2}$$

$N_H = 2N_o$ from H_2O

$$= 2(1.387\times10^{21})$$

$$= 2.77\times10^{21}\ \frac{\text{atoms H}}{dm^2}$$

$$N_{H-Zr} = 2fN_o$$

$$= 2(.15)(1.387\times10^{21})$$

$$= 4.16\times10^{20}\ \frac{\text{atoms H}}{dm^2}$$

$$w_H = \frac{N_{H-Zr} M_H}{N_A}$$

$$= \frac{(4.16\times10^{20})(1)}{6.02\times10^{23}}$$

$$= 6.91\times10^{-4}\ g$$

$$C_H = \frac{w_H\ (10^{-1}\times10^{-1}\times10^{-4})}{P_{Zr}\left(t_o - \frac{\delta}{PBR}\right)}$$

$$= \frac{(6.91\times10^{-4})(10^{-1}\times10^{-1}\times10^{-4})}{(6.5)\left(600 - \frac{2.51}{1.56}\right)}$$

$$= 1.78\times10^{-5}$$

$$\boxed{= 17.77\ wt\ ppm}$$

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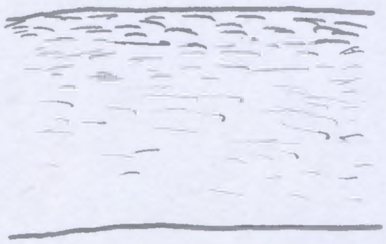
Problem 3 (continued)

-2, Oxide layer?

d) cool



Concentration of hydrides increases as you move towards cooler region.

Problem 4

-2.5, 12.5/15

a) A RIA is a very rapid insertion of reactivity from the loss of a control rod. A LOCA is temperature increase from losing coolant flow rate. During a RIA, the fission rate rapidly increases as well as the temperature. The fuel quickly expands into the cladding. During a LOCA the temperature does not change as quickly. LOCA's can induce a SCRAM, ceasing the fission process. The decay heat will continue to expand the pellet and it may hit the cladding. Without coolant pressure, the cladding is more free to expand.

b) Both cause fuel temperature to increase. Both can cause pellet cladding interactions. Both happen fairly quickly. Both can cause cladding failure

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Problem 4 (continued)

c) ATFP: accident tolerant fuel program

The primary goal of the ATFP is to develop fuel and cladding that can buy the enginrers more time in the event of an accident. These fuel and cladding ideas must be backwards compatible and at least equal in performance to current materials.

A potential ATF concept is sleeves for the cladding. These sleeves could protect the cladding (inside and outside). They may also introduce lower neutron absorption cross sections. These sleeves could prevent coolant channel blockages, buying engineers more time to solve the problem.

-2.5, Cladding coating is to reduce oxidation