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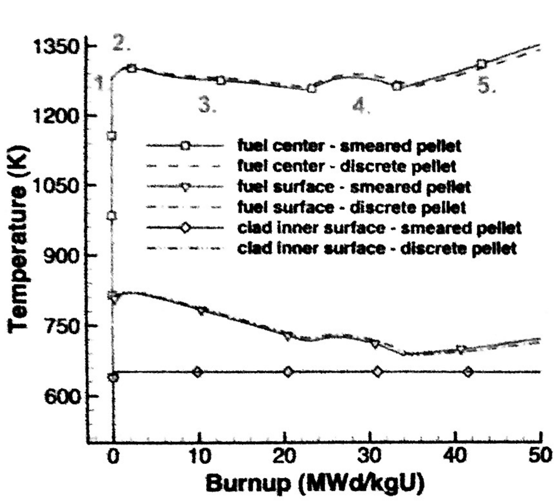
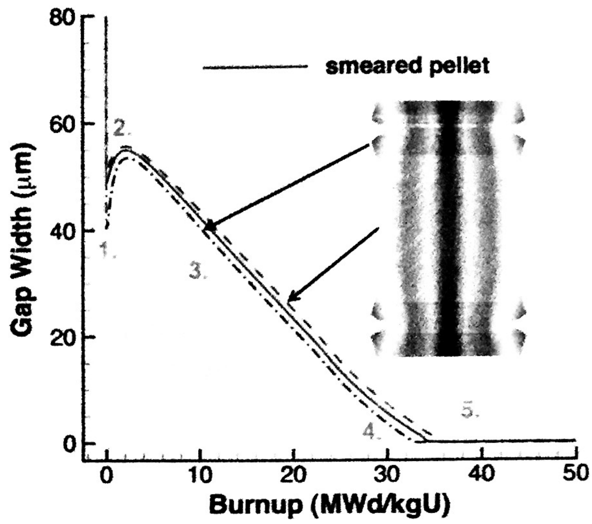
82/100

-1, 24/25

Question 1 (25 points):
The temperature and gap width of a fuel pellet, as predicted by a fuel performance code, is shown below. Using the plots as your guide, determine what is currently occurring within the cladding, gap, and pellet at each number. Note that the numbers are at the same burnups on the two plots.





For each number, describe what is occurring in the cladding, gap, and pellet. Also, describe what features in the plots indicated these behaviors.

1. Rapid thermal expansion decreases the gap initially causing a jump in temperature mostly due to startup

2. Densification occurs causing centerline temp to increase and the gap to increase as well
as

3. Swelling occurs which causes the gap to shrink but also leads to a decrease in temp in the as there is more fuel to conduct heat through and less (worse heat conduction)

4. Fuel is ending swelling and the gap shrinks fission gas release causes an increase in the temp

5. As the gap closes the swelling effect ends and temperature increases as fission gas is released this close also adds to the temperature as thermal conductivity lowers due to collison

-1, T increases due to decrease in fuel k with burnup

Question 2 (30 points) -15, 15/30

A fuel pellet with an average grain size of 8 microns is irradiated with a volumetric neutron flux of 2.0e13 fissions/(cm³ s). Assume the pellet is at a uniform temperature of 900 °C.

a) What is the fission gas diffusion coefficient at this temperature? (5 pts)

$$D = 7.6\times10^{-6}\, e^{\left(\frac{-3.03\,eV}{k_b T}\right)} + 1.41\times10^{-18}\, e^{\left(-\frac{1.19\,eV}{k_b T}\right)} \cdot \sqrt{\dot{F}} + 2.0\times10^{-30}\,\dot{F}$$

$k_b = 8.617\times10^{-5}$ eV/K

$T = 1173$ K

$\dot{F} = 2.0e13$

$$\boxed{D = 8.93\times10^{-17}\ cm^2/s}$$

b) How many gas atoms/cm³ are released from the fuel after 2 years of irradiation? Assume the chain ~~yield y = 0.3017.~~ ~~(10 pts)~~

$$N_{Fy} = y\,\dot{F}_{dot}\,t = \boxed{3.866\times10^{20}\ \frac{atoms}{cm^3}}$$

$t = 6.307\times10^7$

$\dot{F} = 2.0E^{13}$

$y = 0.307$

-6, I asked for gas released, not produced. You need to calculate f and multiply

c) After 2 years of irradiation, the pellet is removed from the reactor and from its cladding, venting all released gas. It is then moved to a furnace and annealed at 2000 °C. Estimate how long before 10% of the gas trapped in the pellet is released. How many gas atoms/cm³ will have been released during this time? (15 pts)

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

$f = .1$

Solving for t in wolfram

$a = 8E^{-4}$ cm

$D = 8.93\times10^{-17}\ cm^2/s$

$$\boxed{t = 76.34\ days}$$

-4, Wrong D, should be at T = 2273 K

-5, You also need to calculate gas released during time

Problem 3 (30 points) -0, 30/30

A ZIRLO cladding tube is in reactor at 600 K for one year. The initial wall thickness is 0.6 mm.

a) What is the oxide weight gain in mg/dm² after this time? (10 pts)

$t^* = 6.62E^{-7} e^{\frac{11947}{600}} = 295$ days

$K_L = 7.48E{-6}\, e^{\frac{-12500}{600}} = .0067$

$\delta^* = 5.1 e^{-550/600} = 2.0392$

$\delta = \delta^* + K_L(t - t^*) = 2.508$ μm

$\delta \cdot 14.7 = w = \boxed{36.87 \ (mg/dm^2)}$

b) What is the ZIRLO wall thickness after this time? (5 pts)

$t_{clad} = 600\ \mu m - \frac{2.508}{1.56} \approx \boxed{598.4\ \mu m}$

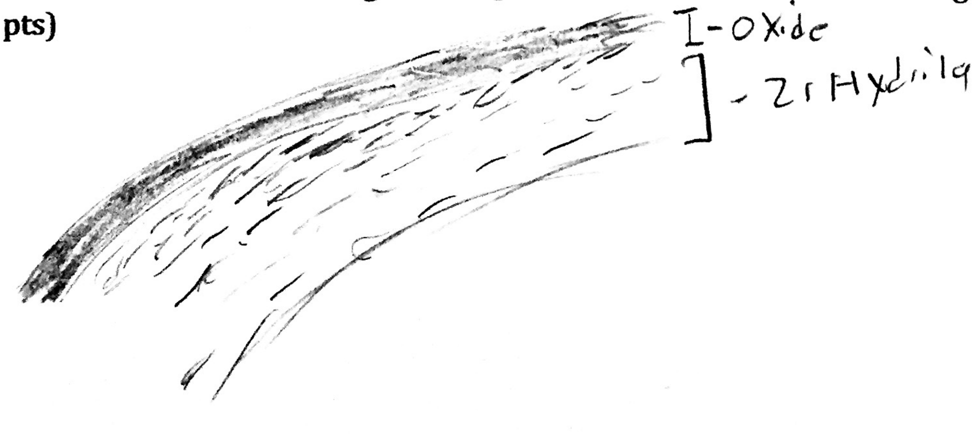
c) Assuming the hydrogen pickup fraction is 15%, what is the weight PPM of hydrogen in the cladding after one year? (10 pts)

$F_{ZrO_2} = \frac{32}{91+32} = .26$

$C_H^{clad} = \frac{2 \cdot f \cdot d \cdot p \cdot \delta \cdot f'_{ZrO_2}}{t - (\delta / PBR)\ \rho_{metal}} \frac{M_H}{M_O} = \frac{2 \cdot (.15) \cdot (2.508) \cdot (226)(5.68) \cdot 1/16}{5.48 \cdot 4 \cdot 6.5}$

$\boxed{17.85 \text{ wt ppm}}$

d) Draw a section of the cladding, showing the various microstructure changes (5 pts)



Problem 4 (15 points)

-2, 13/15

a) What are the primary differences between a loss of coolant accident and a reactivity insertion accident, regarding the fuel and cladding behavior? (5 pts) LOCA is a loss of Coolant accident which means Somewhere in the reactor Setup there is a leak and RIA is sudden change in reactivity In LOCA the cladding can have rapid breakaway oxidation and rapid hydride pickup which does not alway occur in RIA. In LOCA there is alpha beta transition in the fuel

-2, RIA is much faster

b) What are similarities between the fuel and cladding behavior in a RIA and a LOCA? (5 pts)

In both LOCA and RIA the heat in the fuel builds up which causes a rapid pressure increase which causes cracks in the cladding as well as the fuel due to thermal stresses ballooning occurs.

c) List a potential accident tolerant fuel concept and describe how it could meet the primary goal of the accident tolerant fuel program. (5 pts)

The simplest candidate would be to add a coating to the current Ziracloy cladding. Its advantages are it protects the cladding from steam and can be easily implemented soon without much change