73.5/100

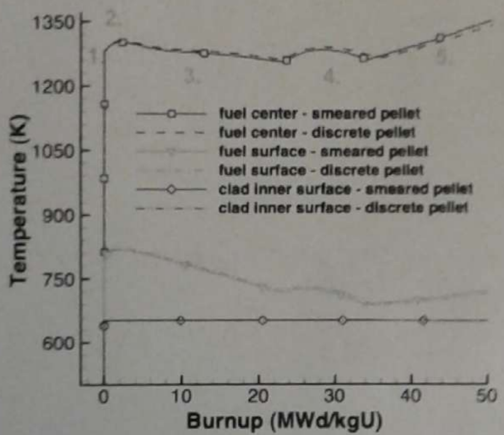
NucE 497 Fuel Performance Exam 2 covering modules 4 – 6

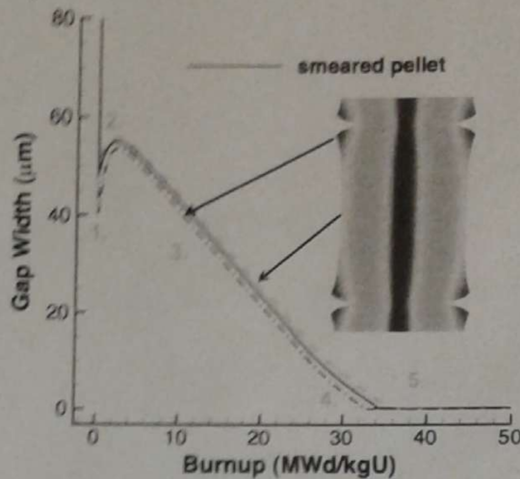
Name: Matthew Ferguson

-14, 11/25

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. This is start up. The fuel & clad expand due to high temp. The gap shrinks as fuel expands more

2. This is densification. The fuel shrinks as pores are filled in. Gap expands. Clad cools.

   -3 Clad temperature stays the same, fuel heats up

3. Fuel swells due to fission products. Gap shrinks. Clad continues to cool. The gap continues to shrink

   -2 Clad temperature stays the same, fuel cools

4. This is when the fuel meets the cladding. The fuel stops swelling due to external pressure from clad. Clad and fuel increase in temp due to better heat transfer

   -4, Gap is not yet zero,
   fission gas release raises T then drops due to more swelling

5. Continued operation results in fuel and cladding.

   -5, Gap now closed, fuel k decreases with burnup, increasing T

-4, 26/30

Question 2 (30 points)

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.

Assume 5% enrichment

$N_u = \frac{9.65 \cdot 6.022e^{23}}{238}$

$N_u = 2.417e^{22}$

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

$k_B = .03$

$D = D_1 + D_2 + D_3$

$D_1 = 7.6\times10^{-6} e^{(-3.03/k_B T)} = 6.79e^{-6}$

$D_2 = 1.41\times10^{-18} e^{\frac{-1.19}{k_B T}} \sqrt{F} = 3.99\times10^{-12}$

$D_3 = 2.0\times10^{-30} F = 2.68e^{-17}$

$D = 6.8 e^{-6}\ cm^2/s$

$F = \phi \cdot q \cdot N_u \sigma$

$F = 2e13 \cdot .05 \cdot 550e^{-24}$

$F = 1.34e^{13}$

-0, Fdot = 2e13

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)

$N_{FG} = y F t$

$N_{fg} = (.3017)(1.34e^{13})(2 \cdot 365 \cdot 24 \cdot 3600)$

$N_{fg} = 2.59\times10^{20}$ atoms/cm³

-0, Fdot = 2e13

$f = 1 - \frac{.0662}{\frac{Dt}{a^2}}\left(1 - .93e^{-\pi^2 \frac{Dt}{a^2}}\right) = .99$

-2, Wrong equation

$\boxed{N_{released} = 2.519\times10^{20}\ \text{atoms/cm}^3\ \text{released}}$

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)

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

$N_{atoms} = 2.59e^{18}$ atoms/cm

$t = 8.2\times10^{-9}$ sec

-2, I can't tell how you calculated the number of atoms in the material

$N_{released} = 2.59\times10^{17}$ atoms/cm³

-6, 24/30

Problem 3 (30 points)

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/dm^2 after this time? (10 pts)

$t(d) = 6.62 \times 10^{-7} e^{(11949/T)}$

$t(d) = 295.0$ days

$\delta(\mu m) = 5.1 e^{\left(\frac{-550}{T}\right)} + 7.48 \times 10^{6} e^{\left(\frac{-12500}{T}\right)} (365 - 295)$

$\delta(\mu m) = 2.51\ \mu m$

$\delta = \frac{\omega}{14.7}$

$\omega = 36.87\ mg/dm^2$

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

$t_{clad} = 600 - \frac{2.51}{1.56} = 598.4\ \mu m$

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

$\delta_{ZrO_2} = 5.68\ g/cm^3 = 1.97\ g/cm$

$N_O = \frac{(0.0368\ 7) N_A}{16} = 1.39 \times 10^{21}$ Atoms

$N_H = (.15)(1.39 \times 10^{21})(2)$

$N_H = 4.16 \times 10^{20}$ Atoms

$\omega_H = 2.07 \times 10^{-4}\ g$

-5, Wrong approach, use equation, also, I can hardly read this

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

-1, Hydride rim? Hydride blisters? CRUD?

-2.5, 12.5/15

Problem 4 (15 points)

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)

RIA cause the fuel to rapidly expand until it hits the cladding, and due to expansion it begins cracking. The force of the expanding pellet will cause cladding failure. In LOCA cladding begins to lose oxidation and pick up hydrogen. It will then ballon and burst. The fuel breaks into peices then relocates to the balloned sections of cladding.

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

The fuel and cladding in RIA & LOCA both have a rapid increase in temperature and fail due to the stresses they are put under.

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)

A potential concept is to improve fuel properties. This will reduce the temperature of the fuel through both a lower operating temperature and improved thermal conductivity. these two things will help reduce the thermal expansion of the fuel and will help prevent fuel breaking apart.

-2.5, What would you do to the fuel to improve the properties?