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EXAM II
(1)

91/100

(1) -3, 22/25

1) The pellet expands due to thermal expansion
The gap size decreases due to pellet thermal expansion
The cladding oxide layer starts to build up & cladding undergoes thermal expansion.

2.) Fuel undergoes densification & the gap size increases, as seen in plot 2. -1, which raises the T

3.) Fuel undergoes fission product swelling & gap width decreases because of this. As gap width decreases, the temperature in the fuel decreases.

4.) The fuel contacts the cladding as the cladding creeps down, closing the gap width. Temperature increases due to fission gas release & a lower thermal conductivity in the gap

5.) The cladding begins to balloon out, blocking coolant channels & causing an increase in fuel temperature

-2, T increases because the fuel conductivity continues to decrease with burnup

(2) -5, 25/30

$a = 8\times10^{-6}\,m$ $\quad \dot{F} = 2.0\times10^{13}$ fiss/$cm^3\cdot s$ $\quad T = 900°C$

a.) $D = D_1 + D_2 + D_3 \;\frac{cm^2}{s}$ $\qquad \dot{F} = q N_u \sigma_f \phi$

$$D_1 = 7.6\times10^{-6}\, e^{-\frac{3.03\,eV}{8.617\times10^{-5}\frac{eV}{K}\cdot(900+273.15)K}}$$

$$D_1 = 7.305\times10^{-19}\ \frac{cm^2}{s}$$

-0, You used eqns from old slides that had typos, D =7.56e+19 gas atoms/cm3

$$D_2 = 1.41\times10^{-21} e^{-\frac{1.19\,eV}{8.617\times10^{-5}\frac{eV}{K}(1173.15K)}}\sqrt{2.0\times10^{13}\frac{n}{cm^3\cdot s}}$$

$$D_2 = 4.468\times10^{-20}\ cm^2/s$$

$$D_3 = 2.0\times10^{-36}\left(2.0\times10^{13}\frac{n}{cm^3\cdot s}\right)$$

$$D_3 = 4\times10^{-23}\ cm^2/s$$

$$\boxed{D = 7.79\times10^{-19}\ \frac{cm^2}{s}}$$

(2) b) $Y = .3017$ using in-pile release

$N_{tot} = Y\dot{F}t = .3017(2.0\times10^{13}\ \frac{n}{cm^3 s})(3600\times24\times365\times2)s$

$N_{tot} = 3.806\times10^{20}\ \frac{\text{gas atoms}}{cm^3}$

$\tau = \frac{Dt}{a^2} = \frac{(7.79\times10^{-19}\ cm^2/s)\cdot(3600\times24\times365\times2)s}{(8\times10^{-4}\ cm)^2}$

$\tau = 7.677\times10^{-5}$

$\frac{1}{\pi^2} = .101 \qquad \tau < \frac{1}{\pi^2}$

$\Rightarrow f = 4\sqrt{\frac{\tau}{\pi}} - \frac{3}{2}\cdot\tau =$

$f = 0.0197$

$N_{rel} = N_{tot}\cdot f$

$\boxed{N_{rel} = 7.48\times10^{18}\ \frac{\text{gas atoms}}{cm^3}}$

c) using post-irradiation annealing

$T = 2000^\circ C \qquad 10\%$

$f = .1 \quad \& \quad f = 6\sqrt{\frac{\tau}{\pi}} - 3\tau$ ← Neglect this term

$.1 = 6\sqrt{\frac{\tau}{\pi}}$

$(.016667)^2 = \left(\sqrt{\frac{\tau}{\pi}}\right)^2$

$2.777\times10^{-4} = \frac{\tau}{\pi} \Rightarrow \tau = 8.726\times10^{-4}$

$D = D_1 + D_2 + D_3$

$D_1 = 7.6\times10^{-6}\, e^{\frac{-3.03}{8.617\times10^{-5}(2273.15)}} = 1.45\times10^{-12}\ \frac{cm^2}{s}$

$D_2 = 1.41\times10^{-21}\, e^{\frac{-1.19}{8.617\times10^{-5}(2273.15)}}\sqrt{2.0\times10^{13}} = 3.242\times10^{-24}$

$D_3 = 2.0\times10^{-36}(2.0\times10^{13}) = 4\times10^{-23}\ cm^2/s$

$D = 1.456\times10^{-12}\ cm^2/s$

$$t = \frac{\tau a^2}{D} = \frac{(8.726\times10^{-4})(8\times10^{-4}\,cm)^2}{1.456\times10^{-12}\,cm^2/s}$$

$$\boxed{t = 383.6\,s = 6.39\,min}$$

-5, How much gas was released?

-1, 29/30

(3) $T = 600K \quad t = 1\,year \quad \delta_o = .06\,cm$

a.) $\delta^* = 5.1\,e^{\frac{-550}{600K}} = 2.039\,\mu m$

$$t^*(d) = 6.62\times10^{-7}\,e^{\frac{11949}{600K}} = 295\,days$$

$$K_L\left(\frac{\mu m}{d}\right) = 7.48\times10^6\,e^{\frac{-12500}{600K}} = 6.7\times10^{-3}\,\mu m/d$$

$$\delta(\mu m) = 2.039\,\mu m + \left(6.7\times10^{-3}\,\frac{\mu m}{d}\right)(365-295)d$$

$$\delta = 2.508\,\mu m$$

$$W = \delta(14.7) = (2.508\,\mu m)(14.7)$$

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

b.) $PBR = 1.56$

-3, Metal is lost not gained and not X2

$$600\,\mu m + \frac{2.508}{1.56}\,\mu m \times 2 = 603.2\,\mu m$$

$$\boxed{\delta_{final} = 603.2\,\mu m}$$

c.) $f_H = .15 \quad \rho_{ox} = 5.68\,\frac{g}{cm^3} \quad \rho_{Zr} = 6.5\,\frac{g}{cm^3}$

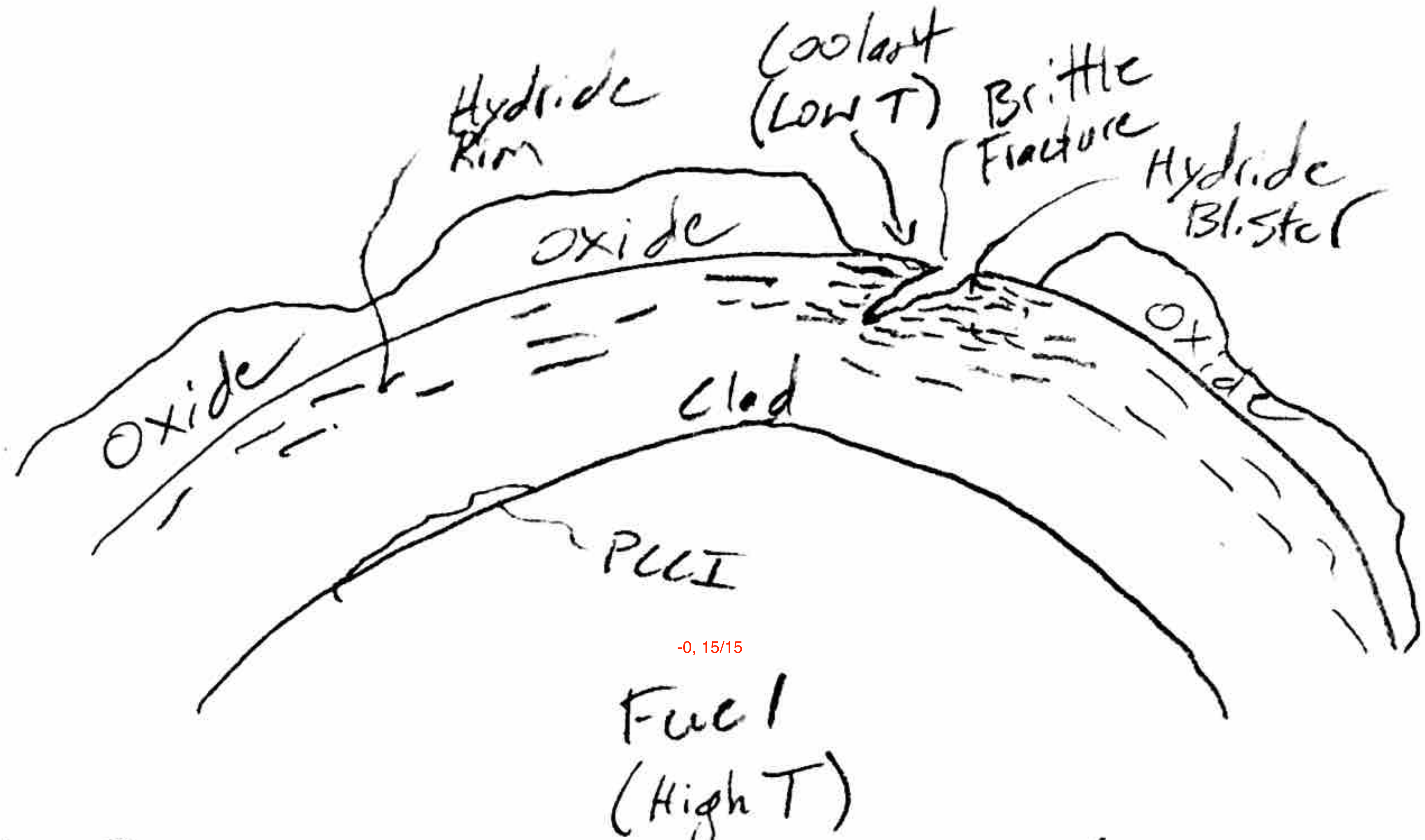
$$C_H^{clad} = \frac{2f\cdot\delta\cdot\rho_{ox}\cdot f^o_{ZrO_2}\cdot\frac{M_H}{M_O}\times10^6}{\left(t-\frac{\delta}{PBR}\right)\cdot\rho_{metal}} \qquad f^o_{ZrO_2} = \frac{2\cdot16}{(2\cdot16+91)} = .26$$

$$C_H^{clad} = \frac{2(.15)(2.508\times10^{-4}\,cm)(5.68\,g/cm^3)(.26)\left(\frac{1}{16}\right)10^6}{\left(600\times10^{-6}\,cm - \frac{2.508}{1.56}\right)6.5\,g/cm^3}$$

$$\boxed{C_H^{clad} = .178 = 17.8\%}$$

-1, Should be 17.87 wt.ppm

3 d.)



-0, 15/15

4 a.) In a RIA, the fuel temperature increases due to increased fission rate & expands rapidly, hitting the cladding & leading to PCMI failures. The temp in the cladding also increases. Pressure increases can cause brittle fracture at low temp or ballooning at high temp. In a LOCA, fission stops, but fuel heats coolant enough to boil off, causing a decrease in external rod pressure. The clad can balloon out, leading to reduced heat transport & increased fuel temp. This can cause fuel melt & fracture & if the cladding bursts, fuel can be dispersed.

b.) Temperatures increase, both can result in ballooning & cladding failure, & fuel dispersal.

c.) FeCrAl as a cladding has high strength & ductility, it's corrosion resistant & doesn't creep much. This is being looked at because this clad material could lead to enhanced fuel containment under accident conditions because it would remain ductile & strong under high temperatures.