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4/21/2017 Nuc E 497 exam

96/100

①

-2, 23/25

1) Reactor starts up, thermal expansion of the fuel, which reduces the size of the gap, Fuel becomes larger

2) Densification of the fuel, increases the temperature, increases the size of the gap, fuel gets smaller

3) Fission product swelling causes the fuel to expand, decreasing the size of the gap, as gap goes down, temp goes down.

4) The Fuel & Cladding come into contact with each other (PCI) Gap size goes to zero, Temperature starts to increase b/c lower thermal conductivity due to burnup

-2, Fission gas release raises fuel T before gap closure

5) Temperature increases due to degrading thermal conductivity from burnup. Possible ballooning of cladding blocking channel flow, which would cause more increases in temperature.

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-0, 30/30

2) a) $\Phi = 2\times10^{13}\ F/cm^3 s \Rightarrow \dot{F}$

$T = 900°C = 1173.15\ K$

$Y = 0.3017$

$t = 2yr = 63072000$

$K_b = 8.617\times10^{-5}$

$a = 8\times10^{-4} cm$

$D_1 = 7.6\times10^{-6} \exp\left(\frac{-3.03}{K_b T}\right)$

$= 7.305027\times10^{-19}$

$D_2 = 1.41\times10^{-21} \exp\left(\frac{-1.19}{K_b T}\right)\sqrt{\dot{F}}$

$= 4.8682366\times10^{-20}$

$D_3 = 2.0\times10^{-36}\dot{F}$

$= 4\times10^{-23}$

-0, you used values from old slides with typos

$\boxed{D = D_1 + D_2 + D_3 = 7.79225\times10^{-19}}$

b) $f = 4\cdot\sqrt{\frac{Dt}{\pi a^2}} - \frac{3}{2}\frac{Dt}{a^2} = 4\sqrt{\frac{(7.79225\times10^{-19})(63072000)}{\pi(8\times10^{-4})^2}} - \frac{3}{2}\frac{(7.79225\times10^{-19})(63072000)}{(8\times10^{-4})^2}$

$f = 0.0196611013$

$\dot{F}yt$ = atoms produced $= (2\times10^{13})(0.3017)(63072000) = 3.80576\times10^{20} \frac{atoms}{cm^3}$

atoms produced $\cdot f = (3.80576\times10^{20})(0.0196611013) = \boxed{7.48255\times10^{18} \frac{atoms}{cm^3} \text{ released}}$

c) $T = 2000°C \Rightarrow 2273.15K$

$f = 10\%$

$D_1 = 1.4556\times10^{-12}$

$D_2 = 1.4501\times10^{-17}$

$D_3 = 4\times10^{-23}$

$\Rightarrow D = 1.4556\times10^{-12}$

$f = 6\sqrt{\frac{Dt}{\pi a^2}}$ (assume short time to negate 2ND Term)

$t = \left(\frac{f}{6}\right)^2\frac{\pi a^2}{D} = \boxed{\begin{array}{l}383.694 sec\\6.395 min\end{array}}$

$3.80576\times10^{20} \frac{atoms}{cm^3}$ produced $- 7.48255\times10^{18} \frac{atoms}{cm^3}$ previously released $= 3.7309345\times10^{20}$ remaining

f(atoms remaining) $= (0.10)(3.7309345\times10^{20}) = \boxed{3.7309345\times10^{19} \text{ released}}$

Assume

$\rightarrow$ No more was produced b/c $\Phi = 0$ out of reactor

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3) a) 600 K

1 Year = 365 days

$t_{Clad} = 0.06\text{cm} = 600\,\mu m$

$\delta^* = 5.1\exp\left(\frac{-550}{T}\right) = 2.03923\,\mu m$

$K_L = 7.48\times10^6 \exp\left(\frac{-12600}{T}\right) = 0.0067003871$

$t^* = 6.62\times10^{-7}\exp\left(\frac{11949}{T}\right) = 295.0071871 \text{ days}$

$\delta(\mu m) = \delta^* + K_L(t - t^*) = (2.03923\,\mu m) + (0.0067)[(365) - (295.007)] \therefore \delta = 2.508209\,\mu m$

$\delta(14.7) = (14.7)(2.508209\,\mu m) = \boxed{36.87067143\ mg/dm^2}$

b) PBR = 1.56

$600\,\mu m + \frac{\delta}{PBR}\times 2 = 603.2154\,\mu m$ Zirlo + Oxide Layer

$600\,\mu m - \frac{\delta}{PBR}\times 2 = 596.784\,\mu m$ Uncorroded Zirlo

Not sure which You want So here is both

-1, Not times 2

c) $C_H^{Clad}[wt.\ ppm] = \frac{2 f \delta \rho_{oxide} f^o_{ZrO_2}\left(\frac{M_H}{M_O}\right)}{\left(t_{clad} - \frac{\delta}{PBR}\right)\rho_{Metal}} \times 10^6$

Using Matlab

$\boxed{C_H^{Clad} = 17.86\ wt\ ppm}$

$\rho_{Metal} = 6.5\,g\,cm^{-3}$

$f^o_{ZrO_2} = 0.2597$

$f = 15\%$ Hydrogen P/u

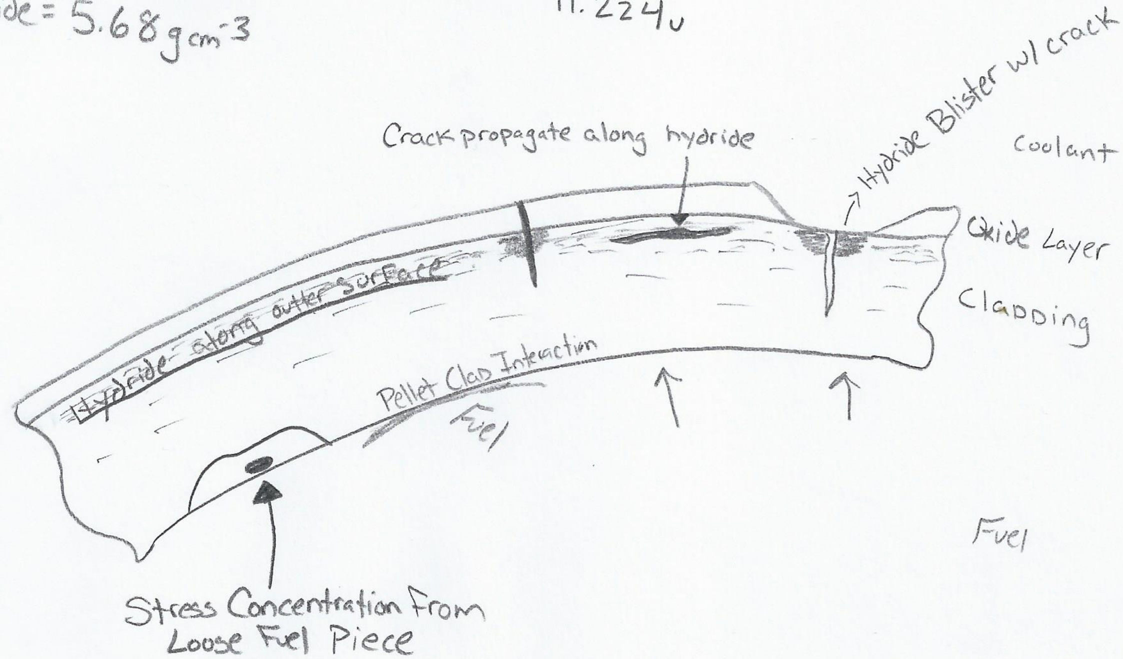
$\rho_{oxide} = 5.68\,g\,cm^{-3}$

$M_H = 1.00794\,u$

$M_O = 15.9994\,u$

$M_{Zr} = 91.224\,u$

D)



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4)

a) With a LOCA, temperature can oscillate depending on start/stop of water flow, and the changing temperature can go for 100+ seconds to longer, but in a RIA it is changing temp in milliseconds. Because LOCA is longer there is a greater chance for ballooning, with RIA, there is a greater chance of cladding fracture. Ballooning for LOCA is also due to loss of external pressure with absense of coolant. In RIA Power sharply increases then goes back down, in LOCA the moderator is gone so power drops significantly, to $\approx \emptyset$.

b) Both accidents cause increased temperature in the fuel, as well as hold possibilities to cause cladding ballooning, or cladding fracture & fuel dispersal. Both accidents have more serious problems with High Burnup Fuel, and both have increased chance of cladding burst due to oxide formation & hydride embrittlement.

c) The goal of ATF is to extend the time before catastropic things happen after an accident, which a silicon carbide composite cladding could accomplish. With the property of having No high temperature creep, it would be able to last longer in a LOCA accident before either ballooning or rupture. A downside is that the microcracks could form, which could cause fission product release. But if you were to layer silicon carbide with an outter shell of Zircaloy -4, you would have the strength of silicon carbide, with the Zircaloy keeping the gas released from the microcracks inside, along with fixing the endcap issue.

-1, Reduced oxidation so less H production