11.7 Actinide Redistribution

Pu and U can redistribute in a fuel pellet to;

1.) Cause Pu to increase at the hot zone (Fig. 11.22) --> Thermal diffusion

2.) Cause U to increase at the pellet surface ---> Vapor transport

Both of these effects change the temperature profile, further aggravating the situation.

11.7.1 Thermal Diffusion of Pu

Check Chapter 7 for more details!

For small Pu concentrations

$$J_{Pu} = -D_{Pu}\left[\left(\frac{\partial C_{Pu}}{\partial r}\right) + \left(\frac{Q^* C_{Pu}}{RT^2}\right)\left(\frac{\partial T}{\partial r}\right)\right] \qquad 1)$$

where Q^* = heat of transport of Pu in the fuel (empirical det'd)

$$\text{and,} \qquad D_{Pu} = D_o \exp\left[-\frac{E}{RT}\right] \qquad 2)$$

Says that Pu migrates down conc. gradient

Says Pu will migrate down a temp. gradient if Q^* is positive and up a temp. gradient if Q^* is negative

Assume $\partial T/\partial r$, $T(r)$ are known or can be solved for.

Assuming that steady state is not achieved during normal fuel lifetime

$$\frac{\partial C_{Pu}}{\partial t} = -\left(\frac{1}{r}\right)\left[\frac{\partial (rJ_{Pu})}{\partial r}\right] \qquad \textbf{3)}$$

(see Eq. 7.6)

Substitute eq. 1) into 3) and solve for $\frac{\partial C_{Pu}}{\partial r}$

also, $C_{Pu}(r, 0) = C^{\circ}_{PuO}$

$C_{Pu}(\infty, t) = C^{\circ}_{PuO}$

(This means that relative diffusion coefficient is so low that nothing changes)

and, $J_{Pu} = 0 \ @ \ r = r_o$ **(central void)**

$J_{Pu} = 0 \ @ \ r = R$

and , $\left(\frac{\partial C_{Pu}}{\partial r}\right)_{r_o} = 0$

See figures 11.23 a&b (note lack of equilibrium)

11.7.2 Vapor Transport

From before (fig. 11.17), we saw that in stoichiometric or hyperstoichiometric fuel, UO_3 is the dominant species.

When fuel pellet contains cracks, UO_3 goes from the hot end to cold end, thus enriching the surface with U.

However, when $\frac{O}{M} < 1.96$***, Pu will also migrate down temp.gradients.***