

Cole Takasugi

1. This assumes 1-D in  $x$ , ( $y, z$  constant)  
steady state and constant thermal conductivity

$$\frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + Q = 0$$

$$k \frac{\partial T}{\partial x} = -Qx + C_1$$

$$\text{using } \frac{\partial T}{\partial x}(x_0) = \frac{\partial T}{\partial x}(0) = 0$$

$$\Rightarrow 0 = C_1$$
$$\Rightarrow \frac{\partial T}{\partial x} = -\frac{Qx}{k}$$

$$T = \frac{Qx^2}{2k} + C_2$$

$$\text{using } T(x_1) = T_1 \text{ and } x_1 = X$$

$$T(X) = T_1 = -\frac{QX}{k} + C_2$$

$$\Rightarrow C_2 = T_1 + \frac{QX}{k}$$

$$\Rightarrow T(x) = \frac{Q(x - X)^2}{2k} + T_1$$

$$\frac{Q(X - x)}{k} + T_1$$

$$2 \quad k_f = 0.5 \frac{\text{W}}{\text{cmK}} \quad K_{\text{gap}} = 25 \frac{\text{W}}{\text{mK}}$$

$$k_{\text{clad}} = 15 \frac{\text{W}}{\text{mK}} \quad k_{\text{coat}} = 5 \frac{\text{W}}{\text{mK}}$$

$$h_{\text{cool}} = 5.5 \frac{\text{W}}{\text{cm}^2\text{K}}$$

$$T_{\text{cool}} = 800\text{K}$$

$$Q = 400 \text{ W/cm}^3$$

$$\begin{aligned} T_{\text{coat}} - T_{\text{cool}} &= \frac{Q R_{\text{fuel}}}{2 h_{\text{cool}}} \\ &= \frac{(400 \text{ W/cm}^3)(0.6 \text{ cm})}{2(5.5 \text{ W/cm}^2\text{K})} = 21.82 \text{ K} \end{aligned}$$

$$T_{\text{clad}} - T_{\text{cool}} = \frac{Q}{2k_{\text{cool}}} R_{\text{fuel}} + t_{\text{cool}}$$

$$= \frac{(400 \frac{\text{W}}{\text{cm}^2})}{2(0.05 \frac{\text{W}}{\text{cmK}})} (0.6 \text{ cm}) (0.1 \text{ cm}) = 24 \text{ K}$$

$$T_{\text{gap}} - T_{\text{clad}} = \frac{Q}{2k_{\text{clad}}} R_{\text{fuel}}$$

$$= \frac{(400 \frac{\text{W}}{\text{cm}^2})}{2(0.15 \frac{\text{W}}{\text{cmK}})} (0.05 \text{ cm}) (0.6 \text{ cm}) = \cancel{44} 40 \text{ K}$$

$$T_{\text{fuel}} - T_{\text{gap}} = \frac{Q}{2k_{\text{gap}}} R_{\text{fuel}} = \frac{Q}{2k_{\text{gap}}} t_{\text{gap}} R_{\text{fuel}}$$

$$= \frac{(400 \frac{\text{W}}{\text{cm}^2})}{2(0.25 \frac{\text{W}}{\text{cmK}})} (0.2 \text{ cm}) (0.6 \text{ cm}) = 96 \text{ K}$$

$$T_0 - T_{\text{fuel}} = \frac{Q}{4k} R_f^2$$

$$= \frac{(400 \frac{\text{W}}{\text{cm}^2})}{4(0.5 \frac{\text{W}}{\text{cmK}})} (0.6 \text{ cm})^2 = 72 \text{ K}$$

$$T_0 = T_{\text{cool}} + 8T_{\text{cool}} + 8T_{\text{clad}} + 8T_{\text{gap}} + 8T_{\text{fuel}} + 8T_{\text{cool}}$$

$$\approx 800 + 21.92 + 24 + 40 + 96 + 72 = 1053.8 \text{ K}$$

at  $r = 0.4$  cm

the final term is  
instead

$$\begin{aligned} T(0.4) - T_{\text{fuel}} &= \frac{Q}{4k} (R - r)^2 \\ &= \frac{(400 \frac{\text{W}}{\text{cm}^3}) (0.6 - 0.4)^2}{4(0.5 \frac{\text{W}}{\text{cmK}})} = 8 \text{ K} \end{aligned}$$

so  $T(0.4) = 989.8 \text{ K}$



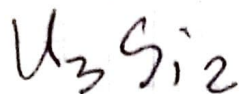
3)

$$\sigma_f = 5706$$

19.5% enrich

$$14.5 \frac{W}{mK}$$

$$\rho = 15.47 \text{ g/cm}$$



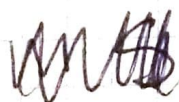
$$a \quad \phi = 2 \times 10^{12} \text{ } \frac{1}{cm^2-s}$$

$$Q = E_f N_f \phi \sigma_f$$



$$m_u = 80.54$$

$$0.905(238) + 0.095(235) = 237.415 \text{ amu}$$



$$m_{Si} = 28$$

$$m_{U_3Si_2} = 3(237.415) + 2(28) = 768.245 \text{ amu}$$

$$N_f = \frac{15.47 \text{ g}}{\text{cm}^3} \frac{1 \text{ mol}}{768.245 \text{ g}} \frac{6.022 \times 10^{23}}{1 \text{ mol}} \frac{3U}{U_3Si_2} (0.095) = 7.18565 \times 10^{21} \text{ fuel atoms/cm}^3$$

$$Q = (200 \times 10^6 \text{ eV}) (1.602 \times 10^{-19} \text{ J/eV})$$

$$(2 \times 10^{12} \frac{1}{cm^2-s}) (7.18565 \times 10^{21} \frac{\text{atoms}}{cm^3}) (570 \times 10^6 \frac{cm^2}{s}) = 212.46 \text{ W/cm}^3$$

3'6) need same  $N_F$

$$\begin{aligned}
 & \text{cancel } 7.18505 \times 10^{21} \frac{1235}{\text{cm}^3} = \cancel{144} \frac{\text{mol}}{6.022 \times 10^{23}} \times \cancel{10.979} \frac{\text{cm}^3}{\text{mol}} \\
 & = \frac{6.022 \times 10^{23}}{\text{mol}} \times \frac{10.979}{\text{cm}^3} \times \frac{14}{142} \times \frac{X_E}{\left( X_E 235 + (1-X_E) 238 + 2(16) \right) \text{g/mol}}
 \end{aligned}$$

$$\rightarrow X_E = 0.29273$$

or 29.273% enriched

4a)

150 W/cm

$$\text{LHR} = 150 \frac{\text{W}}{\text{cm}} \cos\left(\frac{\pi}{2 \cdot 1.1} \left(\frac{1.8 \text{ m}}{1.5 \text{ m}} - 1\right)\right)$$
$$= 143.924 \text{ W/cm}$$

b)

$$\frac{dT}{dz} = \frac{\text{LHR}}{\dot{m} C_p}$$

so larger temp change  
is for lower  $\dot{m} C_p$

$$4200 \cdot 0.22 = 924$$

$$1404 \cdot 0.12 = 168.48$$

so ~~max~~ sodium has  
largest  $dT$



5 forward

$$y(t_0)$$

$$t_0 = 1$$

$$dy/dt = 4 - 3y$$

$$f(t_{0.33}) = f(t_0) + \Delta t \frac{df}{dt_n}$$

$$y(1.33) = 1 + 0.33 [4(1.33) - 3(1.33)^2]$$

$$= 1.33$$

$$y(1.66) = 1.33 + 0.33 [4(1.66) - 3(1.66)^2]$$

$$= 1.334$$

$$y(2) = 1.334 + 0.33 [4(1.97) - 3(1.97)^2]$$

$$= 0.79$$

backward

$$y(1.33) = 1 + 0.33 [4(1.33) - 3(1.33)^2]$$

$$= 1.004$$

$$y(1.66) = 1.004 + .33 (4(1.66) - 3(1.66)^2)$$

$$= 0.467$$

$$y(2) = 0.467 + .33 \dots$$

$$= 0.853$$



6

fissionable can undergo fission by capture of a high energy neutron, fissile can sustain a fission chain reaction for neutrons of any energy. Fertile cannot undergo fission but can be converted to a fissile nuclide by absorption of neutrons and resulting nuclide conversions

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- Pure U metal swells dramatically during thermal cycling
- alpha phase has anisotropic expansion and irradiation growth

8. Mean density is the fraction of internal volume of cell filled by fuel. It is important when considering fissile material density, swelling, and thermal effects that result.

9. Without enrichment, the density of fissile material is too low to sustain fission in LWRs.  $UF_6$  gas is used for enrichment. Centrifuges spin the gas, heavier  $U_{238}$  will be pushed to the outside and lighter  $U_{235}$  to the inside. This is due to centrifugal force, the gas is then drawn from the centrifuge.

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two primary fission  
products species

include

$\text{Mo}$   $A=96$

$\text{Cs}$   $A=133$

which are largely  
produced by fission and  
are near peak values

This is approximate regardless  
of fissioning material



11

Finite difference,  
Finite element,  
and finite volume

finite element is used  
because finite volume  
cannot solve for  
stress and finite  
difference does not allow  
the nonuniformity necessary  
for discrete pellets and  
core heterogeneity