2) $Q = 350 \frac{W}{cm^3}$ $\quad K_c = 0.18 \frac{W}{cm\text{-}K}$ $\quad K_f = 0.04 \frac{W}{cm\text{-}K}$ $\quad h_{cool} = 1.5 \frac{W}{cm^2\text{-}K}$

$R_F = 0.4$ cm $\quad t_g = 30\,\mu m = 0.003$ cm $\quad t_c = 0.05$ cm $\quad T_{cool} = 500K$

$$LHR = \pi R_F^2 Q = \pi (0.4)^2 (350) = 56\pi = 175.93 \ \frac{W}{cm}$$

$$\frac{LHR}{2\pi R_F} = \frac{56\pi}{2\pi (0.4)} = 70$$

$$T_{co} - T_{cool} = \frac{LHR}{2\pi R_f} \frac{1}{h_{cool}} = 70 \frac{1}{1.5} = 46.7 \text{ K} \qquad T_{co} = 546.7 \text{ K}$$

$$T_{ci} - T_{co} = \frac{LHR}{2\pi R_f} \frac{t_c}{k_c} = 70 \frac{0.05}{0.18} = 19.4 \text{ K} \qquad T_{ci} = 566.1 \text{ K}$$

$$T_s - T_{ci} = \frac{LHR}{2\pi R_f} \frac{t_g}{k_g}$$

$$k_g = 16 \times 10^{-4}\, T^{0.79}$$
$$= 16 \times 10^{-4} (566.1)^{0.79}$$
$$= 0.0024 \ \frac{W}{cm\text{-}K}$$

$$T_s - T_{ci} = 70 \frac{0.003}{0.0024} = 87.8 \text{ K} \qquad T_s = 653.9 \text{ K}$$

$$T(r=0.1) - T_s = \frac{LHR}{4\pi k_f} \frac{(R^2 - r^2)}{R_F^2} = \frac{175.93}{4\pi (0.04)} \frac{(0.4^2 - 0.1^2)}{0.4^2} = 328.1 \text{ K}$$

$$\underline{T(r=0.1) = 982 \text{ K}}$$

$$T_c(\text{midpoint}) = \frac{T_{ci} + T_{co}}{2} = \frac{546.7 + 566.1}{2} = \underline{556.4 K}$$

oxide $t_{ox} = 40\,\mu m = 0.004$ cm

$k_{ox} = 0.015 \ \frac{W}{cm\text{-}K}$

$$\Delta T_{ox} = \frac{LHR}{2\pi R_F} \frac{t_{ox}}{k_{ox}} = 70 \frac{0.004}{0.015} = \underline{28 K}$$

$\underline{\uparrow T_0 \text{ by } 28 K}$

3) $L = 3.6\ m$ $\quad z_0 = 1.8\ m$ $\quad LHR^\circ = 400\ W/cm$ $\quad \gamma = 1.25$

$\dot{m} = 0.1\ \frac{kg}{s \cdot m}$ $\quad C_{pw} = 4200\ \frac{J}{kg \cdot K}$ $\quad T_{cool}^{in} = 500K$

LHR @ $z = 2.1$

$$LHR(z) = LHR^\circ \cos\left(\frac{\pi}{2\gamma}\left(\frac{z}{z_0} - 1\right)\right)$$

$$= 400 \cos\left(\frac{\pi}{2(1.25)}\left(\frac{2.1}{1.8} - 1\right)\right) = 391.26\ W/cm$$

$$T_{cool}(z) - T_{cool,in} = \frac{2\gamma}{\pi} \frac{z_0\, LHR^\circ}{\dot{m}\, C_{pw}\, L}\left[\sin\left(\frac{\pi}{2\gamma}\right) - \sin\left(\frac{\pi}{2\gamma}\left(\frac{z}{z_0} - 1\right)\right)\right]$$

$$= \frac{2(1.25)}{\pi} \frac{180(400)}{0.1(4200)}\left[\sin\left(\frac{\pi}{2(1.25)}\right) - \sin\left(\frac{\pi}{2(1.25)}\left(\frac{3.6}{1.8} - 1\right)\right)\right]$$

$$136.4 \quad (0.95 + 0.95)$$

$$T_{cool}(z = 3.6) = 259.2 + 500$$

$$\underline{T_{cool}(z = 3.6) = 759.2\ K}$$

4)

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + Q = 0 \qquad \frac{dT}{dx}(x_0) = 0 \qquad x_0 = 0$$

$$T(x_1) = T_1 \qquad x_1 = X$$

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) = -Q \rightarrow k\frac{\partial T}{\partial x} = -Qx + C_1$$

$$@ x_0 \quad K(0) = -Q(0) + C_1$$

$$C_1 = 0$$

$$k\frac{\partial T}{\partial x} = -Qx \rightarrow T(x) = \frac{-Q}{2K}x^2 + C_2$$

$$T_1 = \frac{-Q}{2K}X^2 + C_2$$

$$C_2 = T_1 + \frac{Q}{2K}X^2$$

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

$$T(x) = T_1 + \frac{Q}{2K}\left(X^2 - x^2\right)$$

1-D, constant K, steady-state

5) UF_6 - Based on mass difference between U-235 and U-238. Gas is spun rapidly in a cylinder. Due to centrifugal forces, the heavier element is slightly enriched at the periphery and the lighter element is slightly enriched at the center. An enriched stream is extracted from the center of the centrifuge. Process is repeated to obtain target enrichment.

6) The CHF is the point on the boiling curve which marks a transition from nucleate boiling to film boiling, corresponding to a drop in the maximum heat flux that can be accomodated by the coolant. If the CHF is exceeded, the coolant can no longer transport all the heat generated, and the fuel/cladding temperature will increase dramatically. The DNBR is the ratio of the CHF to the heat flux in the hottest channel.

7) The relative volume occupied by the fuel inside the cladding, taken as the ratio of the fuel volume to the available volume. $\frac{\pi R_F^2 h}{\pi R_{ic}^2 h} \rightarrow \frac{R_F^2}{R_{ic}^2}$

Necessary to accomodate fuel swelling and cladding creep.

8) Porosity, temperature, fission product precipitates, point defects, etc.

9) Cs, Mo, Zr, Nd, Xe, etc.

Fission products follow a double hump distribution, with one peak near A=95 and the other near A=135.

10) Cladding is the primary containment. Retains fission products, keeps shape of fuel, while being neutron transparent and allowing heat transfer to coolant.

11) Fuel system: fuel, gap, cladding, coolant

12) heat generation & transport
operating under normal conditions w/o outage
ability to function during an accident

13) Finite difference is grid-based, which means that solutions are not continuous, and complex geometries can not be modeled. Limited to 2-D smeared pellet studies, or more coarse.

14) Positive: high melting point, single phase, compatible w/ cladding, radiation resistant, etc.

Negative: brittle, low K_{th}, low U density, sensitive to stoichiometry

15) Explicit makes predictions of a future state based solely on the current state. Implicit makes predictions of the future state using both the current and future states.

1) $Q = E_f N_u \phi \sigma_f$ $\quad \phi = 4\times10^{12}\ n/cm^2 s$ $\quad \sigma_f = 587\ b$ $\quad \rho = 14.3\ g/cc$

$\epsilon_f = 19\%$

$m(UN) = (235 \times 0.19 + 238 \times 0.81) + 14 = 251.43\ g/mol$

$N_u = 14.3\ g/cc \ \frac{1\ mol}{251.43\ g} \ \frac{6.022\times10^{23}\ UN}{1\ mol} \ \frac{1U}{1UN} \times 0.19 = 6.507\times10^{21}\ U^{235}/cm^3$

$Q = (200\times10^6\ eV)\left(1.602\times10^{-19}\ \frac{J}{eV}\right)\left(6.507\times10^{21}\ \frac{U^{235}}{cm^3}\right)\left(4\times10^{12}\ n/cm^2 s\right)$

$\times (587\times10^{-24}\ cm^2)$

$\underline{Q = 489.6\ W/cm^3}$

$N_u(UN) = N_u(UO_2)$ $\quad \rho = 10.97\ g/cc$

$m(UO_2) = 235x + (1-x)238 + 2(16) =$

$m(UO_2) = 270 - 3x$

$6.507\times10^{21} = 10.97\ \frac{1\ mol}{270-3x}\ \frac{6.022\times10^{23}}{1\ mol}\ \frac{1U}{1UO_2} \times x$

$4.85\times10^{-4} = \frac{x}{270-3x}$

$0.266 - 2.95\times10^{-3}x = x$

$\underline{x = 0.265}$