① Patrick Hartwell

$$\int \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)dx = \int -Q \, dx$$

$$k\frac{\partial T}{\partial x} = -Q\,x$$

$$\int_{T_0}^{T_1} k\,\partial T = -Q\int_0^{x_1} x\,\partial x$$

$$T_1 - T_2 = \frac{Q\,x^2}{4k}$$

$$T_0 - T_s \; \frac{QR^2}{4k}$$

(2)

$$T_{clad} - T_{coat} = \frac{Q\, t_{coat}}{2 k_{coat}} R_{fuel} \Rightarrow T_{clad} = 600\,k + \frac{250\frac{W}{cm^3}\cdot 0.01cm \cdot 0.6cm}{2(0.015)W/cmk}$$

$$T_{clad} = 650\,k$$

$$T_{gap} = T_{clad} + \frac{Q\, t_{clad}}{2k_{clad}} R_f = 650 + \frac{250\frac{W}{cm^3}\, 0.05cm\; 0.6cm}{2(0.15\frac{W}{cmK})}$$

$$T_{gap} = 675^{\circ}k$$

$$T_f = T_{gap} + \frac{Q t_{gap} R_{fuel}}{2k_{gap}} = 675 + \frac{250 \cdot 0.6 \cdot 0.005}{2(0.004)}$$

$$T_f = 768.75^{\circ}k$$

$$T_0 = T_f + \frac{Q}{4k} R_f^2 = 768.75^{\circ}K + \frac{250(0.6)^2}{4(0.05)}$$

$$\boxed{T_0 (\text{with Coat}) = 1218.75K}$$

Without Coat or $t_{coat} = 0$

$$T_0 = T_{co} + \frac{Q\, t_{coat}}{2K_{coat}} R_f + \frac{Q t_{clad}}{2k_{clad}} R_f + \frac{Q\, t_{gap}}{2k_{gap}} R_f + \frac{Q R_f^2}{4k}$$

$$T_0 = 600\,k + 0 + 25 + 93.75 + 450 = \boxed{1168.75^{\circ}k}$$

(a)

Heat assumed fission only

$\rho_U = \frac{237}{251} \cdot 12.3\, g/cm = 11.6\, g/cm$

$\rho_{U-235} = 0.195 \cdot 11.6\, g/cm^3 = 2.26\, g/cm^3$

$A = \frac{6.022 \cdot 10^{23}\, \#/mol \;\; 2.26\, g/cm^3}{235\, g/mol} = 5.80 \cdot 10^{21}\, \#/cm^3$

$Q = \sigma_f \cdot A \cdot \phi \cdot 220\, MeV \cdot 1.602 \cdot 10^{-13}\, J/meV$

$Q = 570 \cdot 10^{-24} \cdot 5.80 \cdot 10^{21} \cdot 5 \cdot 10^{12} \cdot 220 \cdot 1.602 \cdot 10^{-13} \;\; \frac{J}{s\, cm^3}$

$\boxed{Q = 582.6 \frac{W}{cm^3}}$

(b)

$\rho_{U-235} = 2.26\, g/cm^3 \qquad \rho_U = \frac{\rho_{U-235}}{e_w} \qquad \rho_{UO_2} = 10.97\, g/cm = \rho_U \cdot \frac{M_U}{M_{UO_2}}$

$10.97 = \left(\frac{\rho_{U-235}}{ew}\right) \cdot \frac{MU}{MUO_2} \qquad ew = \frac{2.26}{10.97} \cdot \frac{237}{269} = 0.1815$

$\boxed{ew\% = 18.2\%}$

(4)

(a) $LHR\left(\frac{z}{Z_0}\right) = LHR^\circ \cos\left[\frac{\pi}{2\gamma}\left(\frac{z}{Z_0}-1\right)\right] = LHR^\circ F\left(\frac{z}{Z_0}\right)$

$Z_0 = 1.75 \quad \gamma = 1.3 \quad Z = 1.4 \quad LHR^\circ = 350 \text{ W/cm}$

$LHR\left(\frac{1.4}{1.75}\right) = 350 \cos\left[\frac{\pi}{2.6}\left(\frac{1.4}{1.75}-1\right)\right] = 350 \cdot 0.971$

$\boxed{LHR\left(\frac{1.4}{1.75}\right) = 340 \text{ W/cm}}$

(b) $Q = LHR^\circ \int_0^{3.5} \cos\left[\frac{\pi}{2\gamma}\left(\frac{z}{Z_0}-1\right)\right] = 9.48 \cdot 10^4 \frac{J}{s}$

$\Delta T = \frac{Q}{\dot{m}c_p} = \frac{9.48 \cdot 10^4 \frac{J}{s}}{0.22 \frac{kg}{s} \cdot 4200 \frac{J}{kg\,K}} = 102.6^\circ K$

$\boxed{T_{out} - T_{in} = 102.6^\circ K}$

(5)

t	dy/dt	y
0.0	0	4.184
0.5	0.184	4.319
1.0	0.135	4.391
1.5	0.075	4.431
2.0	0.037	

$y = y_0 + dy(t)$

$y(0.0) = 4 + 0.184 = 4.184$

$y(0.5) = 4.184 + 0.135 = 4.319$

$y(1.0) = 4.319 + 0.075 = 4.394$

$y(1.5) = 4.394 + 0.037 = 4.431$

(6) Fissile: An isotope with a lower critical threshold after capturing a neutron, than single neutron separation energy.

Fertile: An isotope that will become fissile after capturing a neutron.

Fissianable: An isotope which can fission after capturing a neutron over some threshold energy.

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(7) 1. Dramatic Swelling

2. Too many Phase changes in expected T-P range.

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(8) The ratio of fuel Volume to internal Volume of the fuel element.

useful for swelling limitation estimations

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(9) If we use CANDU reactors we don't.

otherwise it is necesary to have a large enough keff to overcome the additional negative neutron reactivity of the non fuel reactor system.

UF_6 Uranium Hexafluoride

In a centrifuge Particles are stratified by rotational motion according to their molecular mass. Fissile Uranium-235 is sufficiently different from U-238 to allow separation.

(10) $\boxed{\text{Finite (Element, Volume, Difference)}}$

Finite Element is best for high fidelity Simulations.

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(11) DBN: The point where heat transfer becomes impeded by steam insulating the rod surface.

CHF: The point where heat flux peaks from nucleate boiling before begining a transition to film boiling.