REACTOR HEAT PRODUCTION

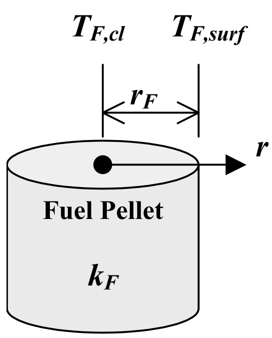
Reactor Thermal Power Generation

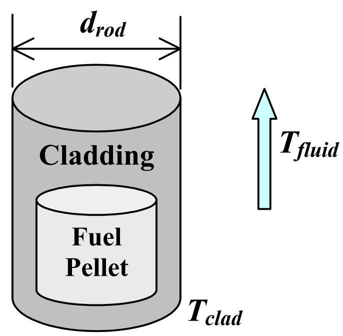
$$P_{Rx} = (Energy\ per\ fission)\,(Fission\ Rate)$$
$$= E_R\, V_{Fuel}\, \Sigma_f\, \phi_{avg}$$
$$= E_R\, \frac{m_{Fuel}}{\rho_{Fuel}}\, N_{Fuel}\, \sigma_f\, \phi_{avg}$$
$$= E_R\, n_{Fuel}\, \sigma_f\, \phi_{avg}$$

where E_R = 200 MeV/fission = $3.20\text{x}10^{-11}$ J/fission.

Temperature Drop in Fuel Pellet ($0 \le r \le r_F$) [UO_2 melts at ≈ 5000°F]

$$\Delta T_{Fuel} = T_{F,cl} - T_{F,surf} = \frac{q'''\, r_F^2}{4\, k_F} = \frac{q'}{4\pi\, k_F}$$





Rod Surface Temperature Drop (T_{clad} < 2200°F to avoid Zirc-Water reaction)

$$\Delta T_{surf} = T_{clad} - T_{fluid} = \frac{q''}{h_S} = \frac{q'}{\pi\, d_{rod}\, h_S}$$

Specific Power, P_s [kW/kg]=[W/g]

$$P_s = \frac{Reactor\ thermal\ power}{Total\ mass\ of\ fissionable\ material} = \frac{P_{Rx}}{m_{Uran}}$$

· note that m_{Uran} is the *fuel loading*

Specific (Fuel) Burnup, B [MW·days/MTU]

$$B = \frac{Energy\ generated\ in\ fuel\ during\ core\ residence}{Total\ mass\ of\ fuel\ (heavy\ metal)} = \frac{\int_0^T P_{Rx}(t)\, dt}{m_{Uran}} = \frac{P_{Rx}\, T}{m_{Uran}}$$

Fuel Residence Time

$$Fuel\ residence\ time = \frac{Fuel\ burnup}{(Specific\ power)\,(Capacity\ factor)} = \frac{B}{P_S\, CF}$$

Reactor Heat Production

Core Basis	Channel (Rod) Basis
Total power produced in reactor core (Q=P_{Rx}) or in a fuel rod (q) [MW]	
$Q = q' H N_{Rods} = q''' V_{Fuel} = E_R \Sigma_f \phi_{avg} V_{Fuel}$ $= \dot{m} \Delta h_{core} = \dot{m} (h_{exit} - h_{inlet})$ $= m c_p \Delta T_{core} = m c_p (T_{exit} - T_{inlet})$	$q_{rod} = \dfrac{P_{Rx}}{N_{Rods}} = q''' \pi r_F^2 H$ $= q'' \pi d_{rod} H = q' H$
Linear power density, q' [kW/cm]	
$q' = \dfrac{Core\ Power}{Total\ active\ fuel\ rod\ length} = \dfrac{P_{Rx}}{N_{Rods} H}$	$q' = \dfrac{q_{rod}}{H} = q''' A_{Fuel} = q''' \pi r_{Fuel}^2$ $= q'' \pi d_{rod}$
Surface heat flux, q'' [kW/cm²] or [Btu/hr·ft²]	
$q'' = \dfrac{P_{Rx}}{Clad\ Heat\ Transfer\ Area}$ $= \dfrac{P_{Rx}}{N_{Rods} \pi d_{rod} H}$	$q'' = h_{surf} (T_{surf} - T_{fluid})$ $= \dfrac{q''' A_{Fuel\ X-sect}}{Rod\ circumf} = \dfrac{q''' r_F^2}{d_{rod}}$ $= \dfrac{q'}{\pi d_{rod}}$
Volumetric heat generation rate, q''' [kW/cm³]	
$q''' = \dfrac{Core\ Power}{Fuel\ Volume} = \dfrac{P_{Rx}}{V_{Fuel}} = E_R \Sigma_f \phi_{avg}$	$q''' = \dfrac{q'}{\pi r_F^2}$
Core power density, P_d [kW/liter] (NOT the same as q''')	
$P_d = \dfrac{Reactor\ thermal\ power}{Total\ core\ volume} = \dfrac{P_{Rx}}{V_{Core}} = \dfrac{4 P_{Rx}}{\pi D_{Core}^2 H}$	$P_d = \dfrac{q'}{(pitch)^2}$