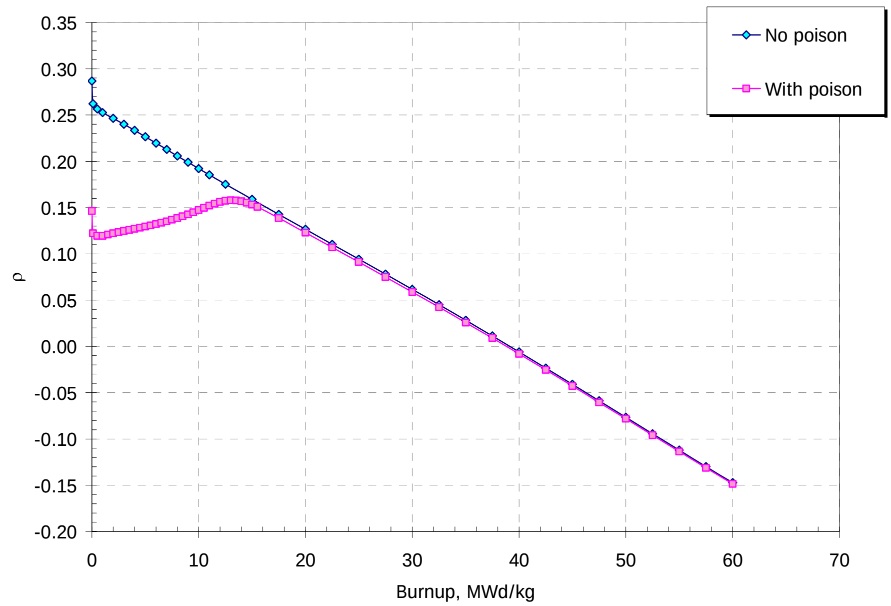
22.251 Systems Analysis of the Nuclear Fuel Cycle
Fall 2009

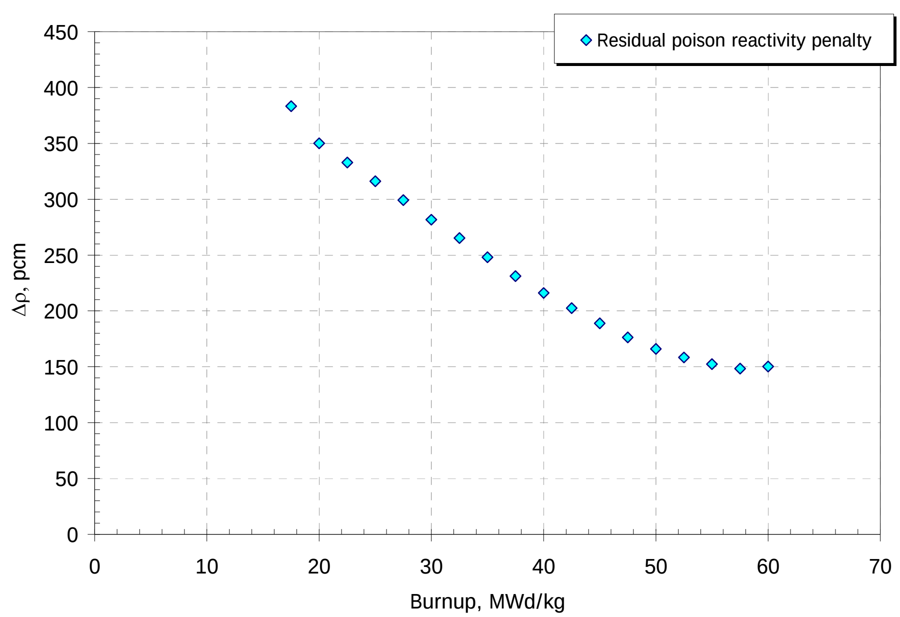
Laboratory Exercise #2 Solution

Using the whole-assembly CASMO-4 PWR input given in class, answer the following:

a) Calculate and plot ρ as a function of burnup up to 60 MWd/kg with and without the burnable poison (Gd). Estimate the residual poison Δρ at high burnup (i.e. 60 MWd/kg).

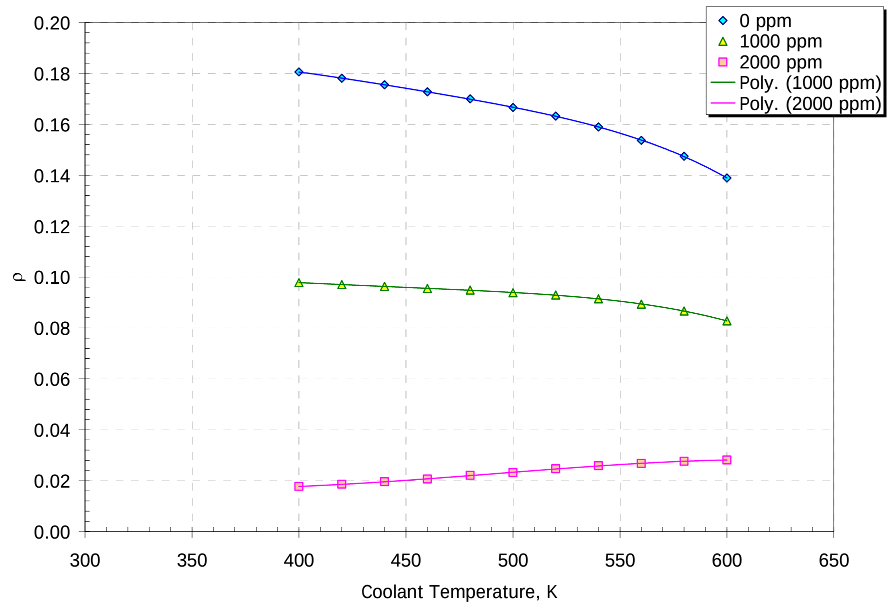


Residual poison reactivity

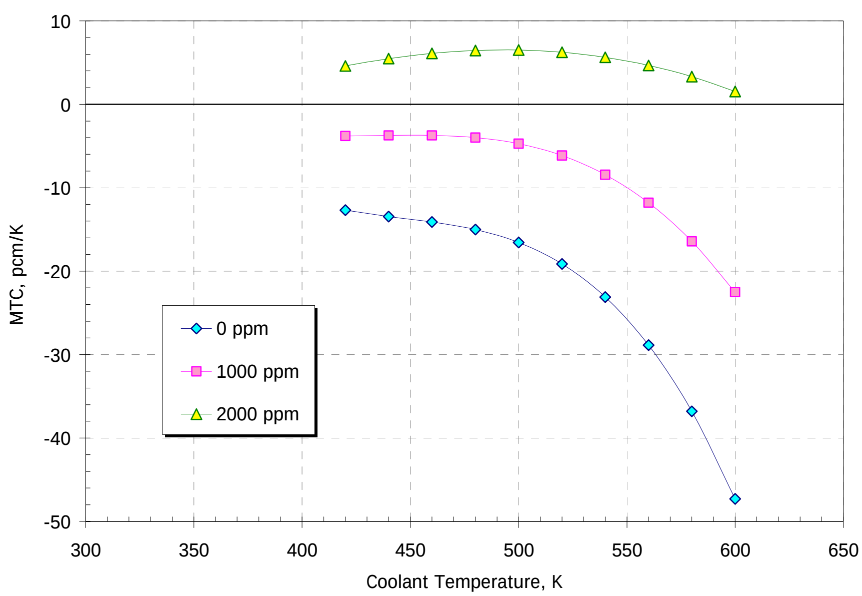


b) At zero burnup calculate the following reactivity feedback coefficients for gadolinium-poisoned fuel assemblies:

1) Plot the MTC as a function of coolant temperature in the range between 400 K and 600 K for three different boron concentrations in the coolant: 0 ppm, 1000 ppm, and 2000 ppm.



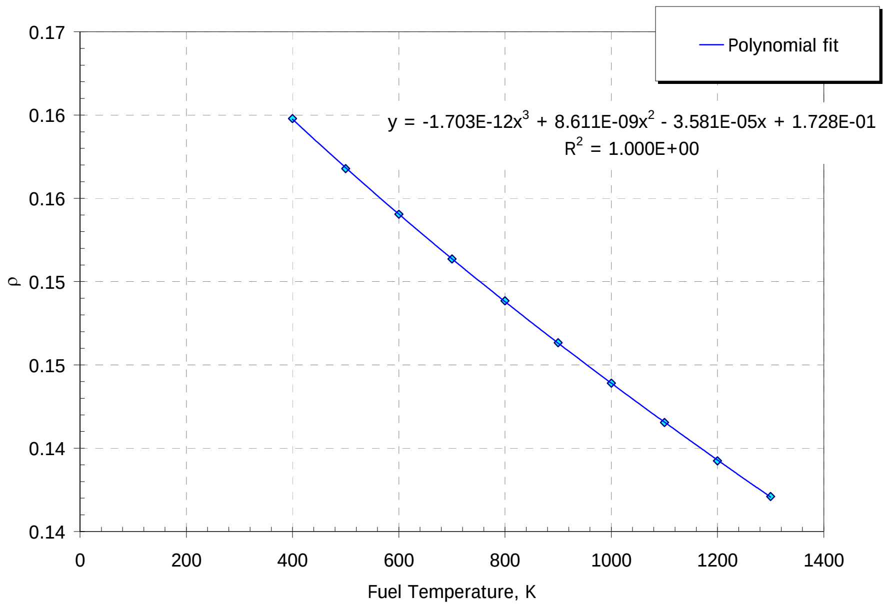
Plot the three MTC vs. temperature curves on the same graph and qualitatively explain the behavior of the curves.



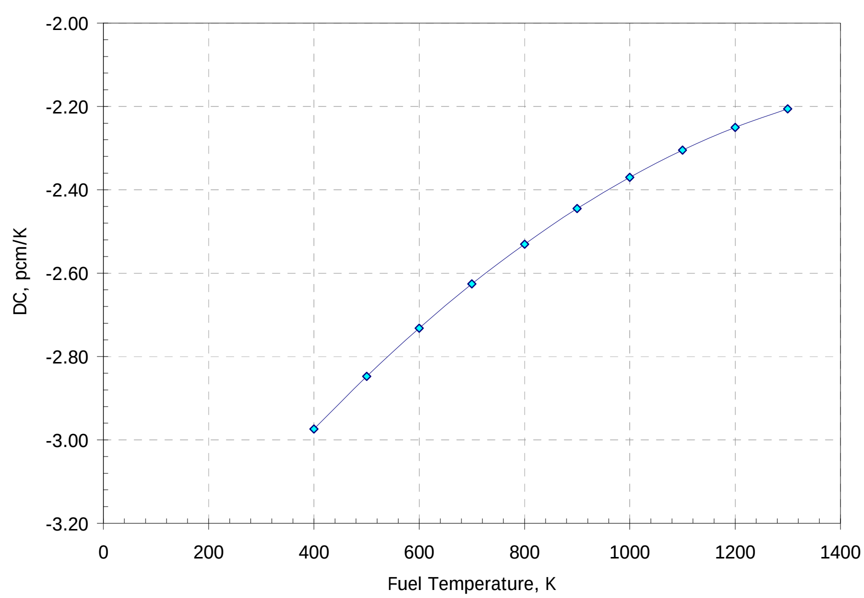
MTC becomes positive with an increase in boron concentration because reduction in water density with temperature also reduces absorption by the boron adding more reactivity than reactivity reduced due to the loss of moderation.

2) Fuel Temperature Coefficient (FTC or Doppler coefficient) in units of $\Delta\rho$ per K by reducing the reference average fuel temperature to 800 K.

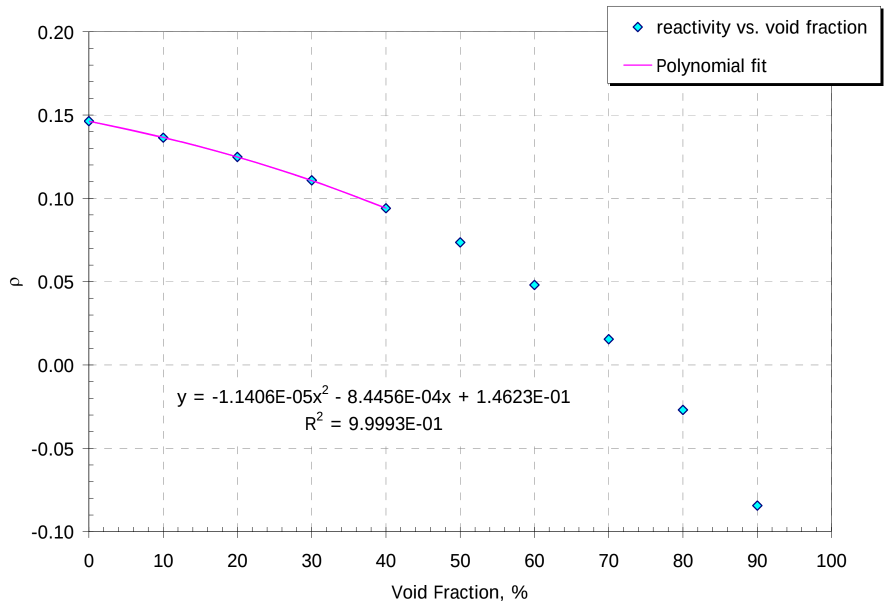
Plot reactivity versus fuel temperature
Fit a polynomial to the calculated data



Calculate the slope at 900K,
DC (900K) ≈ -2.45 pcm/K



3) Void Coefficient (VC) in units of Δρ per %void by reducing the moderator density by 10%.



VC ≈ 84 pcm / %void

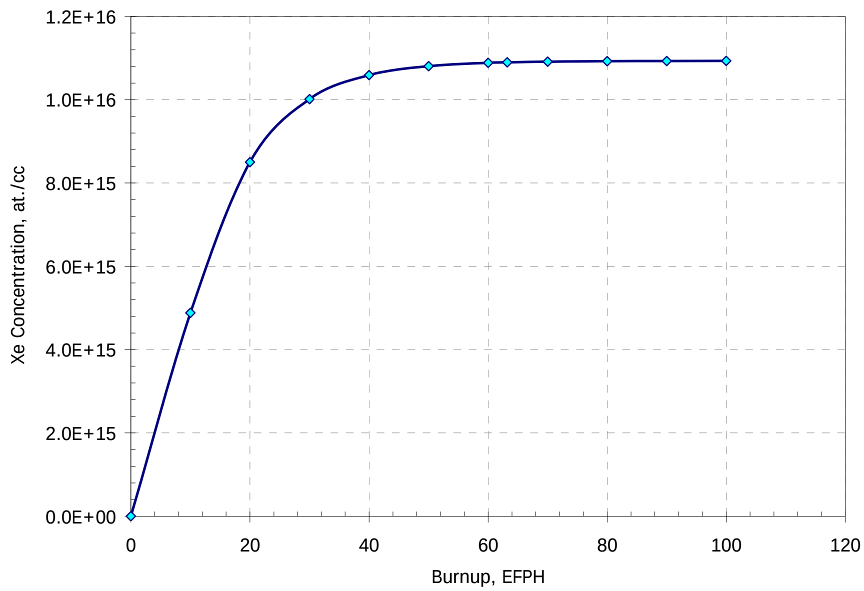
c) Calculate the following additional effects:

Create your own "reactivity ladder" such as attached on the following page by simulating:

1) Δρ from cold zero power (CZP) to hot zero power (HZP) between 30°C and 300°C with isothermal moderator and fuel.
2) Δρ from hot zero power to hot full power (HFP)
3) Δρ due to xenon buildup at HFP by burning for 100 effective full power hours (EFPH)

Case	Xe	T_M, K	T_F, K	ρ, pcm
CZP	0	303	303	20,535
HZP	0	573	573	15,810
HFP	0	573	900	14,983
HFP, XE	Equilibrium	573	900	12,546

Δρ (CZP → HZP) = 20535 – 15810 = 4725 pcm
Δρ (HZP → HFP) = 15810 – 14983 = 827 pcm
Δρ (Xe) = 14983 – 12546 = 2437 pcm



4) Calculate the control rod worth by finding the Δρ between water filled and Ag-In-Cd (AIC) rod filled guide tubes. Assuming that only 53 fuel assemblies out 193 in a typical PWR core have control rods, discuss the factors that will affect the individual control rod worth in the full core.

$\Delta\rho$ (CRDin → CRDout) = 14,634 – (– 16,945) = 31,579 pcm

- Individual control rod worth in the full core will be lower than calculated above because the control rods are not located in every assembly
- The control rod worth depends on the local neutron importance. For example, the worth will be higher in assemblies with high local power density or assemblies located in the core center.
- For the same reason as above, the control rod worth depends on the position (insertion depth) of other control rods in the core.