Due on November 8, 2005

22.251 Systems Analysis of the Nuclear Fuel Cycle
Fall 2005
PROBLEM SET #8

Consider for simplicity a highly idealized, infinite homogeneous reactor containing pure U-235 and an essentially non-absorbing moderator. You may assume negligible fast fission and resonance absorption so the reactor may be treated as an all-thermal system. The focus of this question is on the use of burnable and control absorbers (poison). [See page 81-84. For more realistic case see burnable poison in a heterogeneous system is described in the "Linear Reactivity Model for Nuclear Fuel management", pp90-98.]

At the beginning of life a burnable poison is distributed uniformly to make the supercritical clean fuel reactor just critical. The reactor is to operate at a constant flux ϕ n/cm^2 -sec, which is sufficiently low that Xenon and Samarium buildup may be ignored. After an operational time of T seconds the reactor is to be just critical without using any poison.

(1) Derive an expression for the required microscopic cross section for the burnable poison needed to provide the desired lifetime.

Assume that a burnable poison with the desired microscopic cross section, say σ^0, cannot be found but that elements with microscopic cross sections larger or smaller than the desired value exist.

(2) Consider the case where one makes the reactor critical at t=0 with a burnable poison whose microscopic cross section is <u>less</u> than σ^0. To keep the reactor critical externally governed control rods or soluble poison are used. Sketch the shape of the amount of reactivity controlled by the external control system for the time interval 0 to T. (You may assume the external control is uniformly distributed.) Explain qualitatively.

(3) Consider the case where one makes the reactor critical at t=0 with a burnable poison whose microscopic cross section is <u>greater</u> than σ^0. To keep the reactor critical external control rods and/or soluble poison are used. Sketch the shape of the amount of reactivity controlled by the external control system for the time interval 0 to T. (You may assume the external control is uniformly distributed.) Explain qualitatively.

(4) For the three traces of burnable poison (A,B,C) in Fig.3.3 in "Linear Reactivity Model for Nuclear Fuel management", discuss the advantages and disadvantages of each scheme for the operation of a real core.