NUCL 511 HMWK 2

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1/30/14

Using this CASMO input deck, compute the 1) k-infinity 2) and the nuclide densities of ^{235}U, ^{238}U and ^{239}Pu as a function of burnup. By using CASMO4E on the computer whirlpool.ecn.purdue.edu, a very quick burnup calculation can be done [2]. The k-infinity and the nuclide densities of Uranium and Plutonium can be drawn out of the output file provided. These are all plotted in Figure 1.

Figure 1a clearly shows the decrease in k-infinity over the burnup of a reactor. This starts out steep, but then levels off. This happens because initially, only ^{235}U is fissioning, so it is quickly removed. As it fissions, though, it creates ^{239}Pu, which can also fission. The production of ^{239}Pu is what slows the drop in k-infinity. This can be verified by watching the concentrations of ^{239}Pu and ^{235}U. ^{235}U concentration drops throughout the entire lifetime of the reactor, whereas ^{239}Pu increases the entire lifetime. Note the differences in magnitude between these two concentrations, several orders of magnitude. This shows how much ^{239}Pu contributes to the reactivity of a reactor, even at tiny concentrations. Also note that the ^{238}U leads directly into production of ^{239}Pu, and this is why it decreases slightly as ^{239}Pu increases. ^{238}U is orders of magnitude higher than the other concentrations because this is a simulation of a low enriched fuel reactor.

Using the delayed and total neutron emission spectra and applying linear interpolation in the group around $1\,MeV$, estimate the fractions of total and delayed neutrons that can cause fast fission in ^{238}U, assuming a sharp threshold at $1\,MeV$. From Table 2-V [1], the emission spectra for delayed and total neutrons can be plotted as heavy lines in Figure 2. This plot shows χ vs. E (with E on a logarithmic scale). This is equivalent to plotting χ vs $\max(u) - u$, and gives the best visual representation of the data.

The fraction of neutrons that can cause fast fission is given by

$$f = \frac{\int_0^\infty \sigma_{ff}(E')\chi(E')dE'}{\int_0^\infty \chi(E')dE'}$$

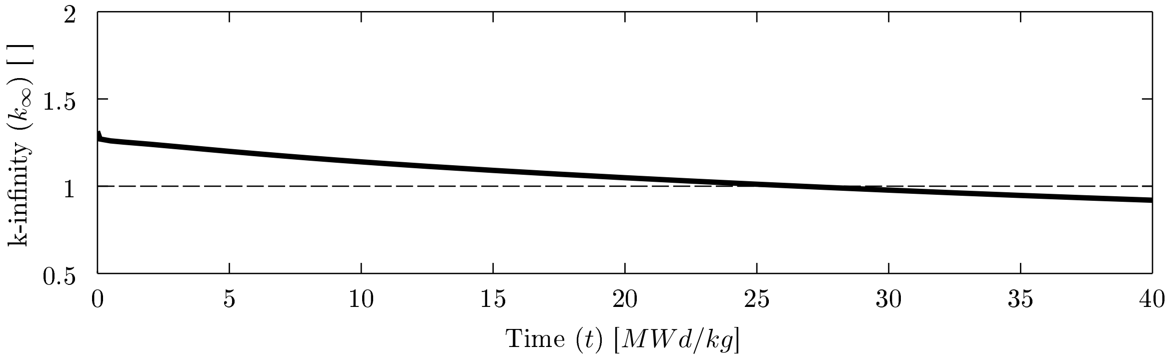
where σ_{ff} is the cross section of fast fission, or rather in this definition the ability to create fast fission. By assuming the threshold of fast fission is sharp at $1\,MeV$, σ_{ff} is now a heaviside step function of $1\,MeV$ ($\sigma_{ff} = H(1\,MeV)$). This effectively changes the integrations limits, where the fraction now able to cause fast fission is given by

$$f = \frac{\int_{1\,MeV}^\infty \chi(E')dE'}{\int_0^\infty \chi(E')dE'}$$

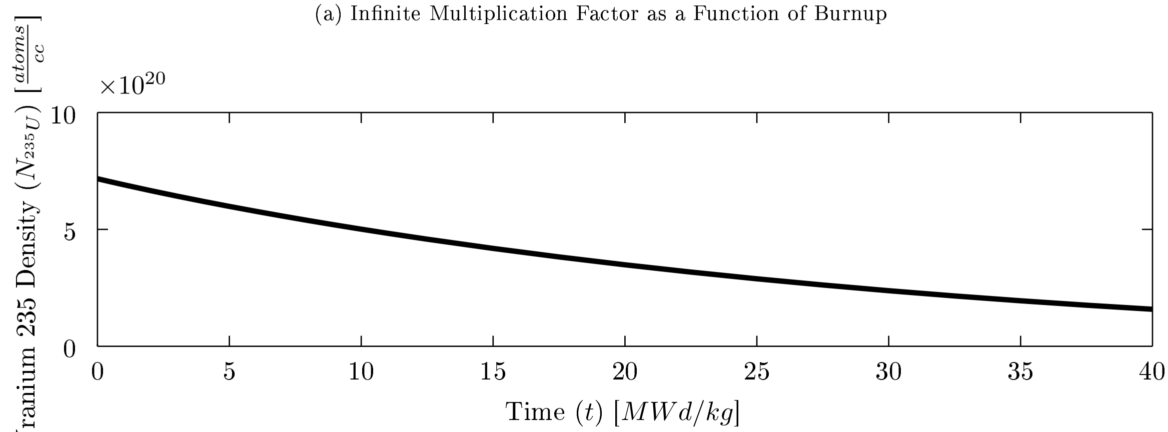
Note that the integration is done in energy and not in lethargy because the threshold is given in energy. Linear interpolation must be performed around $1\,MeV$ to determine the fraction of that group that are above $1\,MeV$, and this is also done in energy. The shaded area underneath the total χ curve in Figure 2 illustrates the integral. Table 1 lists the results of the integration for each different χ. The results show that the spectrum emitted from delayed neutrons is much softer than that emitted for prompt.

Table 1: Fraction of Emitted Neutrons able to Induce Fast Fission for Delayed and Total Emission Spectra

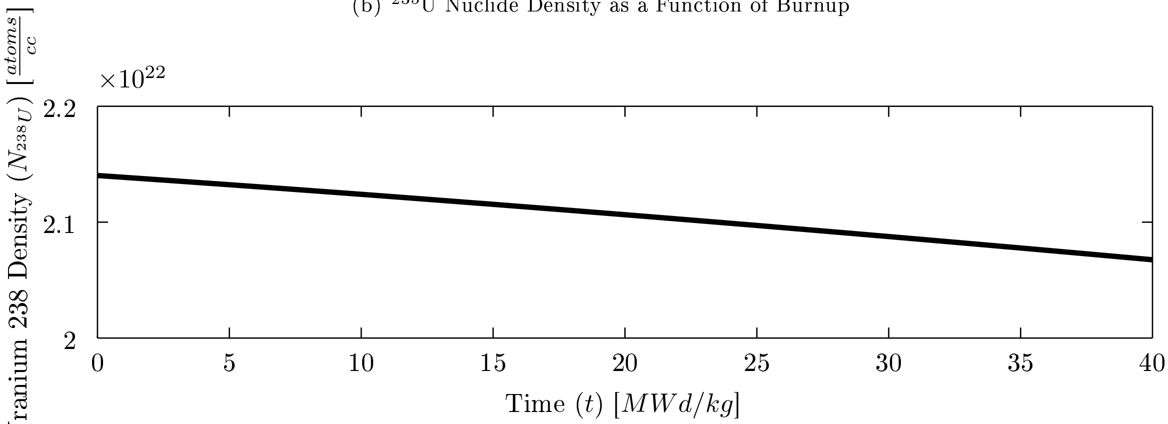
	χ_1	χ_2	χ_3	χ_{456}	χ
Delay Group	1	2	3	$4-6$	$1-6$+prompt
Fraction	~ 0	~ 0	~ 0	8.6×10^{-8}	0.680



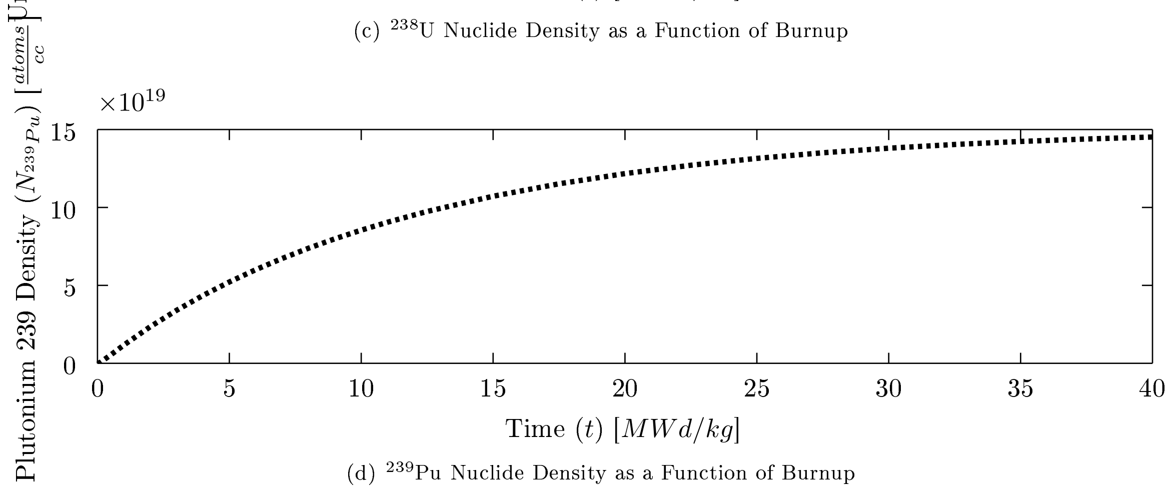
(a) Infinite Multiplication Factor as a Function of Burnup



(b) ^{235}U Nuclide Density as a Function of Burnup



(c) ^{238}U Nuclide Density as a Function of Burnup



(d) ^{239}Pu Nuclide Density as a Function of Burnup

Figure 1: Infinite Multiplication Factor and Nuclide Densities as a Function of Burnup for CASMO4E

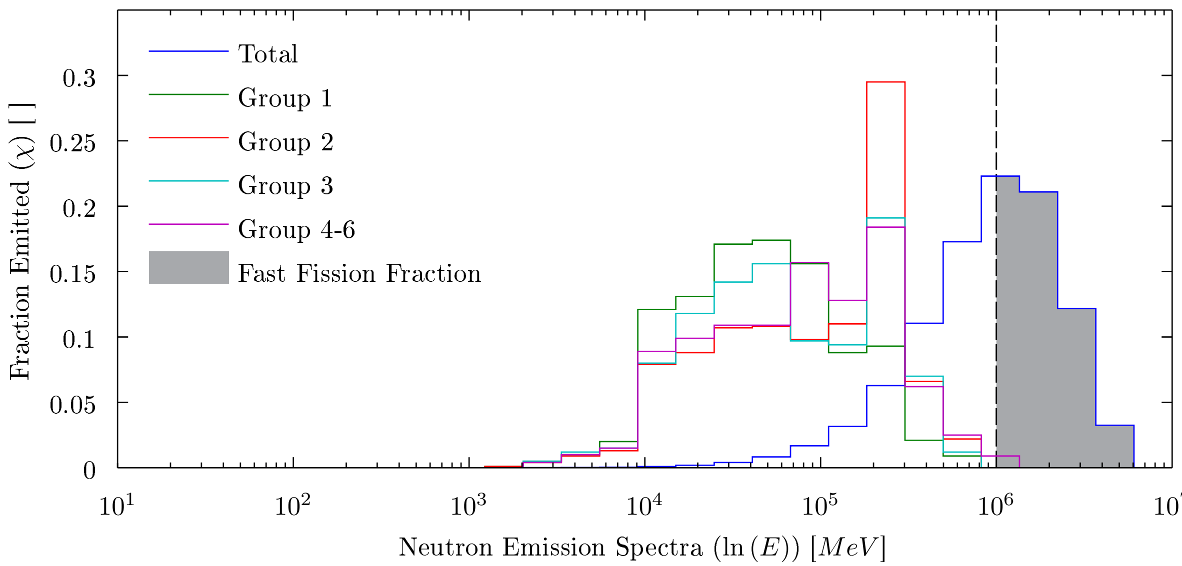


Figure 2: Emission Spectra of Delayed and Total Neutrons from Fission

References

[1] K Ott and R Neuhold. *Introductory Nuclear Reactor Dynamics.* American Nuclear Society, La Grange Park, Illinois, 1985.

[2] Studsvik. CASMO-4E User's Manual. Technical report, Studsvik Scanpower, Inc., 2009.