CH4960
Project - 1

Infinite multiplication factor with enriched uranium as fuel and light water as moderator*

Area occupied by uranium in a fuel rod ($A_{u,fr}$) $= \pi (5)^2$

$= 78.53\ mm^2$

Area occupied by zirconium in a fuel rod ($A_{zr,fr}$) $= \pi (5.5)^2 - 5^2)$

$= 16.49\ mm^2$

Area of cross-section of the bundle wall ($A_{zr,b}$) $= (212)^2 - (210)^2$

$= 844\ mm$

Number of fuel cells in a bundle = 196

Area occupied by uranium in a bundle (A_u) $= 196\, A_{u,fr}$

$= 15393.80\ mm^2$

Area occupied by zirconium in a bundle (A_{zr}) $= 196\, A_{zr,fr} + A_{zr,b}$

$= 4076.70\ mm^2$

Area occupied by water in a bundle (A_w) $= 222^2 - A_u - A_{Zr}$

$= 29813.5\ mm^2$

Amount of U per metre depth of a bundle (n_u) $= \frac{A_u \rho_u}{M_u}$

$= 12.35$ moles

Amount of Zr per metre depth of a bundle (n_{Zr}) $= \frac{A_{Zr} \rho_{Zr}}{M_{Zr}}$

$= 2.91$ moles

Amount of water per metre depth of a bundle (n_w) $= \frac{A_w \rho_w}{M_w}$

$= 16.5$ moles

Amount of H per metre depth of a bundle (n_H) $= 2n_w$

$= 33$ moles

Amount of O per metre depth of a bundle (n_O) $= n_w$

$= 16.5$ moles

Assuming 3% enrichment of U-235

$\Rightarrow$ Number of moles of U-235 ($n_{U\text{-}235}$) per metre of a bundle $= 0.03\, n_U$

$= 0.37$ moles

Number of moles of U-238 ($n_{U\text{-}238}$) per metre of a bundle $= 0.97\, n_U$

$= 11.98$ moles

We will use all of this data in the Monte-Carlo simulation along with the following assumptions:

- The casing is made using a Zr alloy with a high percentage of Zr in it. Therefore, we assume it to be made up of pure Zr-90.

- The moderator is pure H_2O, with no other isotopes of H and O present.

- Sufficient cross section data was not available for all elements across the entire neutron energy spectrum. Necessary steps have been taken to ensure sufficient accuracy.

- Neutrons having less than 1 meV are assumed

to have been captured (this speeds up the simulation since these neutrons do not have enough energy to cause fission, so they keep scattering until they are captured).

- Neutrons which have less than 10 keV of energy do not cause fission in U-238 (because only fast neutrons can cause fission in U-238).
- Neutrons which have greater than 1eV of energy do not cause fission in U-235 (because only thermal neutrons can cause fission in U-235).

Running the script gives us:

$$k_\infty = 1.18$$

* Note: Since the roll number of the first member of the team ends with **4**, we took enriched uranium as fuel and light water as moderator as per the given instructions.

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