# NUCE497 HW-1 Solutions

Q-1)

**Given:**

- fuel enrichment → 3.5 %
- thermal neutron flux → $2.8\times10^{13}$ n/cm²-s

**Assumptions:**

- Negligible contribution from U238, Pu239, etc. → $\sigma_f \approx \sigma_f^{35} = 550\,b = 5.5\times10^{-22}$ cm, $N_f \approx N_f^{35}$
- 95 % of the energy released from fission is converted to heat → $E_f = 0.95(200\ \text{MeV/fission}) = 190$ MeV/fission OR $= 3\times10^{-11}$ J/fission

$$Q[W/cm^3] = \underbrace{\boxed{E_f}}_{3\times10^{-11}\,J/s}\ \underbrace{\boxed{N_f^{35}}}_{\text{unknown}}\ \underbrace{\boxed{\sigma_f^{35}}}_{5.5\times10^{-22}\,cm^2}\ \underbrace{\boxed{\phi_{th}}}_{2.8\times10^{13}\,n/cm^2 s}$$

where $N_f^{35} = 0.035\,N_u$

We need to calculate $N_u$ for each material as follows:

$$N_u = \frac{\rho_u^* N_A}{M_u}$$

where $\rho_u^*$ is uranium density in the given material.

$M_u = (0.035)\,235 + (1-0.035)\,238 = 237.9$ g/mol

| $\rho_u^*$: | $N_u[\times10^{24}$ atoms/cm³$]$ | $N_u^{35} = 0.035 N_u$ [atoms/cm³] | $Q$ [W/m³] |
|---|---|---|---|
| $UO_2$ → | $\frac{\rho_{UO_2} N_A}{M_u} = \frac{(9.65)(0.6022)}{237.9} = 0.0244$ → | $8.55\times10^{20}$ | ~395 |
| metal fuel → | $\frac{\rho_u N_A}{M_u} = \frac{(19.04)(0.6022)}{237.9} = 0.0482$ → | $1.69\times10^{21}$ | ~779 |
| UC → | $\frac{\rho_{UC} N_A}{M_u} = \frac{(12.97)(0.6022)}{237.9} = 0.0328$ → | $1.15\times10^{21}$ | ~531 |
| UN → | $\frac{\rho_{UN} N_A}{M_u} = \frac{(13.52)(0.6022)}{237.9} = 0.0342$ → | $1.20\times10^{21}$ | ~553 |
| $U_3Si_2$ → | $\frac{\rho_{U_3Si_2} N_A}{M_u} = \frac{(11.31)(0.6022)}{237.9} = 0.0286$ → | $1\times10^{21}$ | ~463 |

Q-2)

a) Main fissile atom fissioned in my reactor will primarily be U235 exists in fuel and Pu239 which will be generated from U238 by neutron absorption.

b) $UO_2$ will be used due to its high melting temperature, thermal stability due to its seramic form, relatively good corrosion resistance which is crucial in terms of safety existence of relatively more experience on its behavior in normal operation or transient.

c) Coolant will be used to remove the heat generated in the fuel to keep its temperature below the limits enabling us safe reactor operation. Super critical water will be used due to its very high heat capacity. Working with such coolant can provide additional safety feature in such a way that it does not boil in case of loss of coolant.

d) Reactor coolant can be increased as much as desired due to the lack of phase change.

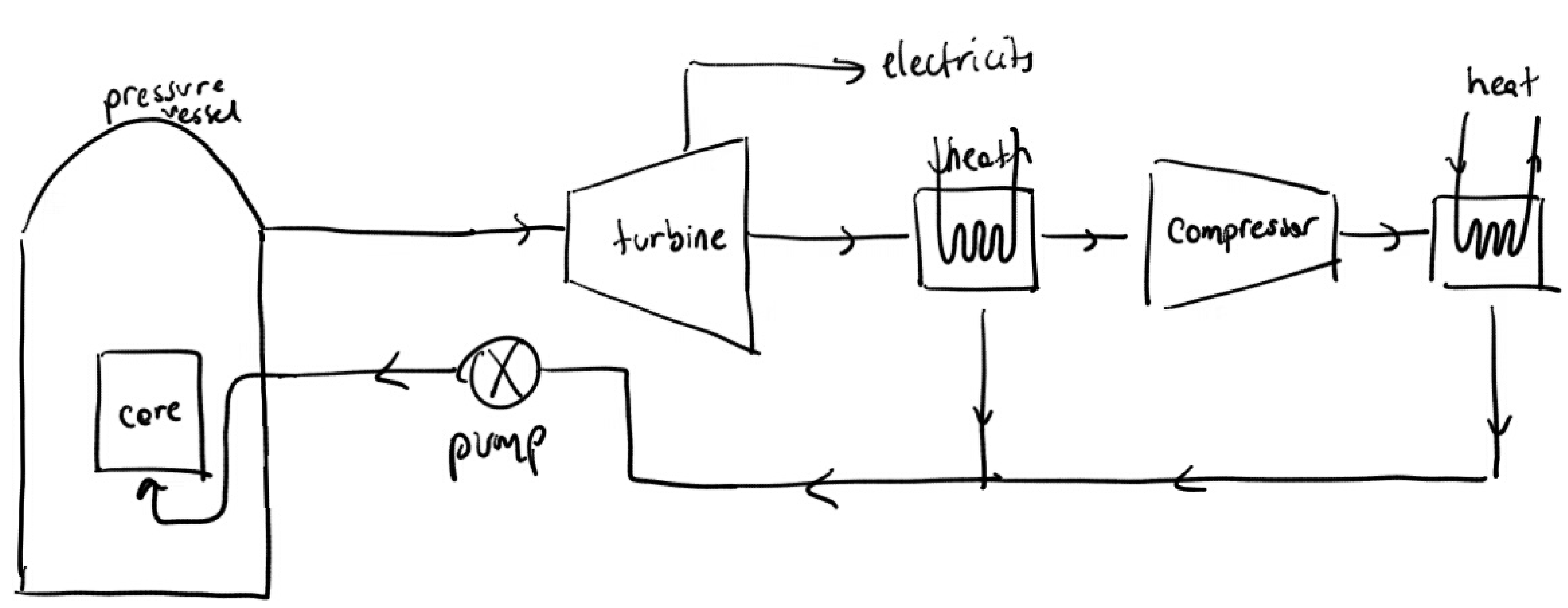
High heat will primarily be used for hydrogen generation. This approach is expected to be more profitable in long term compared with electricity production. by considering the limited amount of natural resources.

e) Thermal neutrons will be used. Since the density of the coolant is expected to be very low, it is necessary to use additional moderator (Be, $H_2O$, $D_2O$ etc.) having relatively higher density.

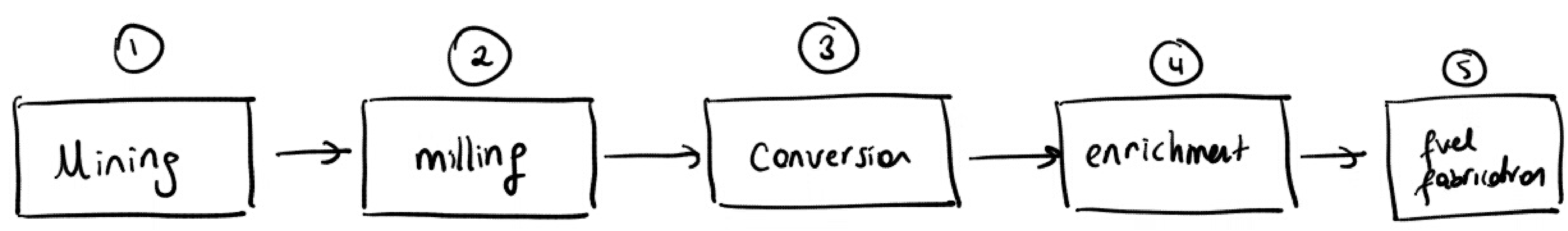
f) Fuel consists of $UO_2$ pellets with cladding similar to LWRs. However, stainless steel will be used due to its high temperature corrosion resistance. Fuel geometry will be cylindrical similar to LWRs forming N×N square fuel assembly. Unlike typical LWRs, additional channels will be added for the moderator to flow.

Once-through cycle is considered; spent fuels are removed and stored in the spent fuel pool for its activity to reduce. After the vitrification, vitrified fuels will be stored in dry storage casks.

8)




Q-3)




1. Mining: Natural uranium with 0.7 %. is mined in $UO_2$ form and sent for milling.

2. Milling: Mined $UO_2$ is milled to a fine powder. Yellow cake in $U_3O_8$ is formed after a series of chemical processing

3. Conversion: $U_3O_8$ yellow cake is converted into $UF_6$ (0.7%) for enrichment process. Conversion to $UF_6$ is essential since it is in gas form at room temperature.

4. Enrichment: $UF_6$ (0.7 %) is enriched to $UF_6$ (3-4%) with a series of successive enrichment steps. Enrichment can be done by using ; gas diffusion technique, gas centrifuge technique or laser extraction. Most common one is either gas diffusion or gas centrifuge. In these techniques, $UF_6$ enrichment is increased step by step to 3-4%. During this process, large amount of energy is consumed. Such energy is provided from additional power plants which are generally constructed next to the enrichment facility.

5. Fuel fabrication: 3-4% enriched $UF_6$ is converted to powder $UO_2$ with a desired stoichiometry. Pellets are then formed and sintered to get seramic form with a desired grain size for best performace. Due to the thermal expansion during the reactor operation, these pellets are champered on the shoulders and dimpled at the center to keep integrity of the fuel cladding as much as possible