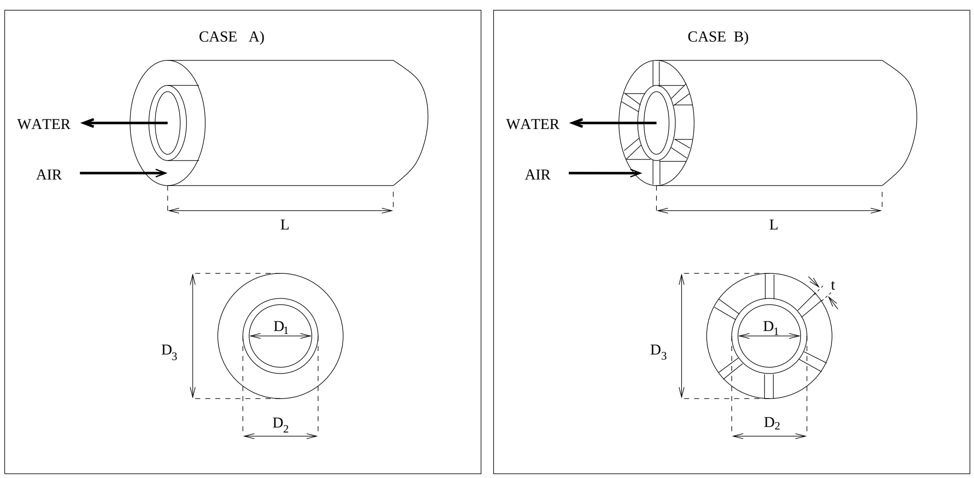
MAE 101C: Heat Transfer. Design Project.

A counterflow, concentric tube heat exchanger of a *cogeneration system* is designed to heat water from an inlet temperature $T_{wi} = 5°\text{C}$ to a required outlet temperature $T_{wo} = 60°\text{C}$, for which heat from an exhaust air stream at $T_{ai} = 600°\text{C}$ is recovered. The water stream is flowing through the inner tube at a mass flow rate of $\dot{m}_w = 1\text{kg/s}$, while the air stream passes through the annular region at a mass flow rate of $\dot{m}_a = 0.5\text{kg/s}$. Two different configurations are available for the design: A) two concentric tubes, B) an inner tube connected by six fins to an insulated outer tube. The thickness of the fins is $t = 2\text{mm}$. The length of the tubes is L. Fins and tubes are made of the same carbon steel $k = 50\text{W/mK}$. The maximum specified length the heat exchanger can occupy in the system is 15m, design lengths above that are prohibited by space availability constraints. For the required outlet temperature $T_{wo} = 60°\text{C}$ of the water stream and both configurations A) and B):

1. Obtain the outlet air temperature T_{ao} when the heat exchanger operates in steady conditions.
2. Calculate the overall heat transfer coefficient or thermal conductance $U \cdot A$ as a function of the tube length L.
3. Calculate the Logarithmic Mean Temperature Distribution ΔT_{lm}.
4. Calculate the mean temperature increment ΔT_m by using an approximate correction factor $F = 0.5$.
5. Calculate the effectiveness ε of the heat exchanger and the number of heat transfer units NTU.
6. Estimate the length L of the tubes needed for the specified temperature conditions. Comment on the effect of adding fins and state the best design A) or B) based on 1) material cost and 2) space availability.



Dimensions: $D_1 = 24\text{mm}$, $D_2 = 30\text{mm}$, $D_3 = 60\text{mm}$, $t = 2\text{mm}$.

Thermodynamic properties of air ($T \sim 380°\text{C}$): $\rho_a = 0.525\text{kg/m}^3$, $Pr_a = 0.71$, $k_a = 0.0473\text{W/mK}$, $\nu_a = 61.52 \cdot 10^{-6}\text{m}^2/\text{s}$, $c_{pa} = 1056\text{J/kgK}$.

Thermodynamic properties of water ($T \sim 33°\text{C}$): $\rho_w = 995\text{kg/m}^3$, $Pr_w = 5.04$, $k_w = 0.620\text{W/mK}$, $\nu_w = 0.757 \cdot 10^{-6}\text{m}^2/\text{s}$, $c_{pw} = 4176\text{J/kgK}$.

Write a clear, <u>clean</u> and neat solution, carefully explaining each step, assumption and calculation.