1. River water at 20°C is used to cool the condenser in a steam power plant. The steam enters the condenser as a saturated vapor at 50 kPa, and exits as a saturated liquid at the same pressure. The mass flow rate of the steam is 20 kg/s. Calculate the mass flow of river water needed to condense the steam, given the constraint that the maximum temperature rise of the river water is 5°C. You can use a specific heat relation to calculate the change in enthalpy of the river water: \( \Delta h = C \Delta T \), with \( C = 4.18 \) kJ/kg·K.

\[
\begin{align*}
\dot{Q} - \dot{W} &= \dot{m}_h \cdot h_{h_2} + \dot{m}_c \cdot h_{c_2} - \dot{m}_h \cdot h_{h_1} - \dot{m}_c \cdot h_{c_1} \\
\dot{Q} - \dot{W} &= \dot{m}_h \cdot (h_{h_2} - h_{h_1}) + \dot{m}_c \cdot (h_{c_2} - h_{c_1})
\end{align*}
\]

\( \dot{Q} = 0 \) because overall device is adiabatic.

\[
\begin{align*}
\dot{m}_h (h_{h_2} - h_{h_1}) &= \dot{m}_c (h_{c_2} - h_{c_1}) \\
\Rightarrow \dot{m}_h &= \dot{m}_c
\end{align*}
\]

or

\[
\dot{Q}_{\text{from hot}} = \dot{Q}_{\text{to cold fluid}}
\]

\[
\begin{align*}
\dot{m}_h \cdot h_{h_2} &= \dot{m}_h \cdot h_{h_1} @ 50 \text{ kPa} \\
&= \text{latent heat} @ 50 \text{ kPa}
\end{align*}
\]

cold: liquid \( h_2 \): \( \Delta h = C \cdot \Delta T \)

water: \( C = 4.18 \) kJ/kg

Finite essay: contribution is important

Integrating over time of a process...

\[
\begin{align*}
\int \frac{dU}{dt} &= U_2 - U_1 = m_{u_2} - m_{u_1} \\
\int \dot{Q} dt &= Q_{1-2} \\
\int \dot{W} dt &= W_{1-2} \\
\int m_{\text{in}} h_{\text{in}} dt &= 0 \\
\int m_{\text{out}} h_{\text{out}} dt &= 0
\end{align*}
\]

2. Last topic: Unsteady state, unsteady flow up until now: SSSF:

* \( \dot{m} \) are constant
* \( C\) & flow properties constant, neglect KE, PE

\[
\begin{align*}
\text{in} \rightarrow CV \rightarrow \text{out} \quad \frac{dU}{dt} &= \dot{Q} - \dot{W} \\
\text{mass} \quad \frac{dm}{dt} &= \dot{m}_{\text{in}} - \dot{m}_{\text{out}}
\end{align*}
\]

3. What can we do now look at specific situations where we can perform the integrals.

1. Filling a tank from a supply line.
2. Pressure cooker problem.

Tank filling problem

\[
\begin{align*}
\frac{V}{V_{\text{final}}} &= \text{supply line} \quad \text{initially tank is at state 1: } \bar{M}_1, T_1, P_1, \ldots \\
\text{open valve: fluid flows in...} \\
\text{valve closed: tank is now at state 2: } M_2, T_2, P_2, \ldots
\end{align*}
\]
→ typically given: properties of the supply line: \( P_{in}, T_{in} \), etc.
→ \( \dot{V} \) of tank = const. \( W_{in} = 0 \)
\[
M_2 U_2 - M_1 U_1 = Q_{in} - (M_1 - M) h_{in}
\]
Supply line: we can assume \( h_{in} = \text{constant} \)
\[
\int h_{in} \, dt = h_{in}, \quad \int M \, dt = M_{in} = \text{mass that flowed in}
\]

→ say we are dealing w/ air
→ const. \( C_p, C_v \)
\[
U = C_v T (T_{in} \text{ K})
\]
\[
h = C_p T (T_{in} \text{ K})
\]
\[
U_2 = h_{in} \implies C_v T_2 = C_p T_{in}
\]
or \( \implies T_2 = \frac{C_p}{C_v} T_{in} \)
→ \( \frac{C_p}{C_v} = 1.4 \)

→ how much mass \( \Delta m \)?
\( Q_{in} = 0 \) (adiabatic)
\[
M_2 U_2 - M_1 U_1 = Q_{in} - \int \dot{W}_{in} = M_{in} h_{in}
\]
→ \( M_1 = 1 \text{ kg}, U_1 = P_1 \text{ atm} + U_1 = 0 \)
→ \( h_{in} = h @ 200 \text{ kPa, } 200^\circ \text{C} \)
→ \( M_{in} = M_2 - M_1 \)
\[
M_2 U_2 - M_1 U_1 = (M_2 - M_1) h_{in}
\]
\[
M_2 = \frac{V}{U_2}
\]

→ \( M_{in} = M_2 - M_1 \) & conservation of mass:
\[
M_2 U_2 - M_1 U_1 = Q_{in} + (M_1 - M) h_{in}
\]

examples:
→ tank is initially empty: \( M_1 = 0 \)
→ tank is insulated: \( Q_{in} = 0 \)
\[
M_2 U_2 = M_1 h_{in} \implies U_2 = h_{in}
\]

say \( T_{in} = 300 \text{ K} \)
\[
T_2 \approx 1.4 \cdot 300 = 420 \text{ K}
\]
and \( P_2 = P_{in} \)

→ \( V = 0.1 \text{ m}^3 \), containing 1 kg of \( H_2O \) at 1 atm pressure.
connected to a line containing steam @ 200 kPa, 200°C.
open line, tank fills, \( P_2 = 200 \text{ kPa} \)

→ need state 2; need to get \( \dot{V}_2, U_2, P_2 \)
\[
P_2 = 200 \text{ kPa}
\]
→ guess \( U_2 \) & \( T_2 \) to get \( U_2 \rightarrow M_2 = \frac{V}{U_2} \)
→ \( U_2 = \frac{1}{M_2} (M_1 U_1 + (M_1 - M) h_{in}) \)
→ does \( U_2 = U @ T_2 \text{ or } P_2 \)?