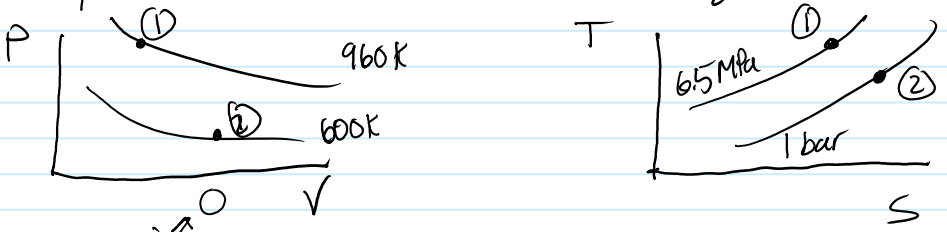
# Entropy for Control Volumes Example

**Given:**
- Air in an insulated turbine operating at steady state
- $P_1 = 6.5\ MPa$, $T_1 = 687°C$ (Inlet)
- $P_2 = 1\ MPa$, $T_2 = 327°C$ (Exit)
- $\Delta KE = \Delta PE = 0$

**Determine:**
- Work per kg
- If the process is internally reversible, irreversible, or not possible

State (1)
$T_1 = 687°C + 273 = 960\ K$

State (2)
$T_2 = 327°C + 273 = 600\ K$




$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + \dot{m}(h_1 - h_2)$$

$$\dot{W}_{cv} = \dot{m}(h_1 - h_2)$$

$$\boxed{\frac{\dot{W}_{cv}}{\dot{m}} = h_1 - h_2}$$

$$\frac{\dot{W}_{cv}}{\dot{m}} = \frac{kJ/\cancel{s}}{kg/\cancel{s}} = kJ/kg$$

$$0 = \sum \frac{\dot{Q}}{T} + \dot{m}(s_1 - s_2) + \dot{\sigma}_{cv}$$

$$\dot{\sigma}_{cv} = -\dot{m}(s_1 - s_2)$$

$$\boxed{\frac{\dot{\sigma}_{cv}}{\dot{m}} = s_2 - s_1}$$

$$s_2 - s_1 = \left(s_2^\circ - s_1^\circ\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

Table A-1

@ $T_1 = 960K \Rightarrow h_1 = 1000.55\ kJ/kg$ $\quad s_1^\circ = 2.92128\ kJ/kg \cdot K$

@ $T_2 = 600K \Rightarrow h_2 = 607.02\ kJ/kg$ $\quad s_2^\circ = 2.40902\ kJ/k \cdot K$

$$\frac{\dot{W}_{cv}}{\dot{m}} = 1000.55\ kJ/kg - 607.02\ kJ/kg$$

$$\boxed{\frac{\dot{W}_{cv}}{\dot{m}} = 393.53\ kJ/kg}$$

$$s_2 - s_1 = \left(2.40902\ kJ/kg \cdot K - 2.92128\ kJ/kg \cdot K\right) - \left(0.287\ kJ/kg \cdot K\right) \ln\left(\frac{1\ MPa}{6.5\ MPa}\right)$$

$$s_2 - s_1 = 0.02492\ kJ/kg \cdot K$$

$$\frac{\dot{\sigma}_{cv}}{\dot{m}} = 0.02492\ kJ/kg \cdot K > 0 \Rightarrow \text{Irreversible}$$