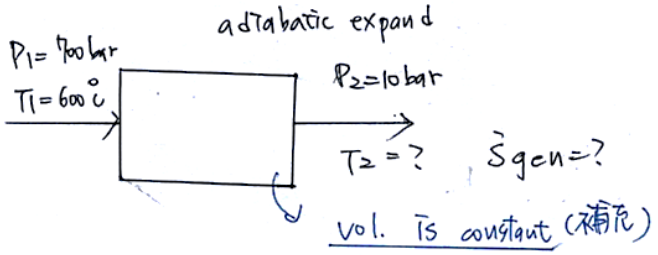
4.4 Steam at 700 bar and 600°C is withdrawn from a steam line and adiabatically expanded to 10 bar at a rate of 2 kg/min. What is the temperature of the steam that was expanded, and what is the rate of entropy generation in this process?

4.4



From mass balance

$\frac{dM}{dt} = \dot{M}_1 + \dot{M}_2 \Rightarrow \dot{M}_2 = -\dot{M}_1$ — ①

(for steady state ← flow rate is constant)

From energy balance

$\frac{dU}{dt} = \dot{M}_1\hat{H}_1 + \dot{M}_2\hat{H}_2 + \dot{Q} + \dot{W}_S - P\frac{dV}{dt}$

(steady state; adiabatic; no shaft work; vol. is constant)

$\Rightarrow \dot{M}_1\hat{H}_1 + \dot{M}_2\hat{H}_2 = 0$ — ②

from eq'n ① $\dot{M}_2 = -\dot{M}_1$

$\Rightarrow \hat{H}_1 = \hat{H}_2$ from Molller Diagram $\hat{H}_1 = 3063$ kJ/kg

$\Rightarrow \hat{H}_2 = 3063$ kJ/kg

$\Rightarrow$ from Molller Diagram $\hat{S}_1 = 5.5$ kJ/kg.K. $\hat{S}_2 = 7.3$ kJ/kg.K

$T_2 = 308$ °C #

From entropy balance

$\frac{dS}{dt} = \sum_{k=1}^{k} \dot{M}_k\hat{S}_k + \frac{\dot{Q}}{T} + \dot{S}_{gen}$

(steady state)

$\Rightarrow \dot{S}_{gen} = -\dot{M}_1\hat{S}_1 - \dot{M}_2\hat{S}_2$

$= -\dot{M}_1(\hat{S}_1 - \hat{S}_2) = -2$ kg/min $(5.5 - 7.3)$ kJ/kg.K

$= 3.6$ kJ/min.K.