Summary

The entropy balance of an *open system* is given as:

$$\underbrace{\dot{S}_{in} - \dot{S}_{out}}_{\substack{\text{Rate of net entropy} \\ \text{transfer by heat and mass}}} + \dot{S}_{gen} = \Delta \dot{S}_{system}$$

$$\sum \frac{\dot{Q}_k}{T_k} + \sum \dot{m}_{in} s_{in} - \sum \dot{m}_{out} s_{out} + \dot{S}_{gen} = \frac{dS_{syst}}{dt}$$

T_k in the heat transfer term can correspond to the temperature of the system (fluid) or the temperature of the thermal energy reservoir (TER). The choice of temperature influence the meaning of $\dot{S}_{gen}$:

$T_k = T_{f\,luid} \Rightarrow \dot{S}_{gen}$ represents the entropy generation *within the system*

$T_k = T_{TER} \Rightarrow \dot{S}_{gen}$ represents the entropy generation *for the process*

For an *ideal gas* with constant specific heats:

$$h_2 - h_1 = c_p (T_2 - T_1)$$

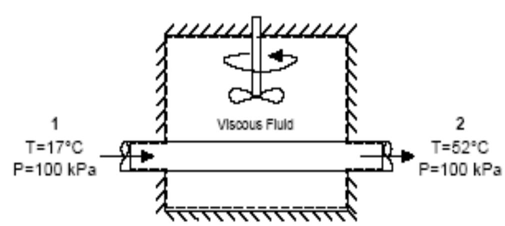
$$s_2 - s_1 = c_{p,avg} \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right) \qquad s_2 - s_1 = c_{v,avg} \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{v_2}{v_1}\right)$$

$$s_2 - s_1 = c_{v,avg} \ln\left(\frac{P_2}{P_1}\right) + c_{p,avg} \ln\left(\frac{v_2}{v_1}\right)$$

Question

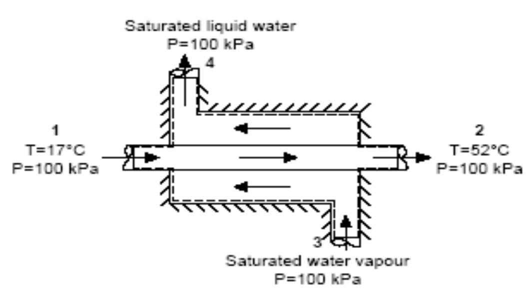
Two alternative systems are under consideration for bringing a stream of air from 17°C to 52°C at an essentially constant pressure of 100 kPa. For each of the two systems, calculate the rate of entropy production, in kJ/k per kg of air through the system.

System 1: The air temperature is increased as a consequence of the stirring of a liquid surrounding the line carrying the air



System 1

System 2: The air temperature is increased by passing it through one side of a counter-flow heat exchanger. On the other side, steam condenses at a pressure of 100 kPa from a saturated vapour to a saturated liquid. Both systems operate under steady conditions and are sufficiently insulated to prevent significant heat transfer with the surroundings.



System 2