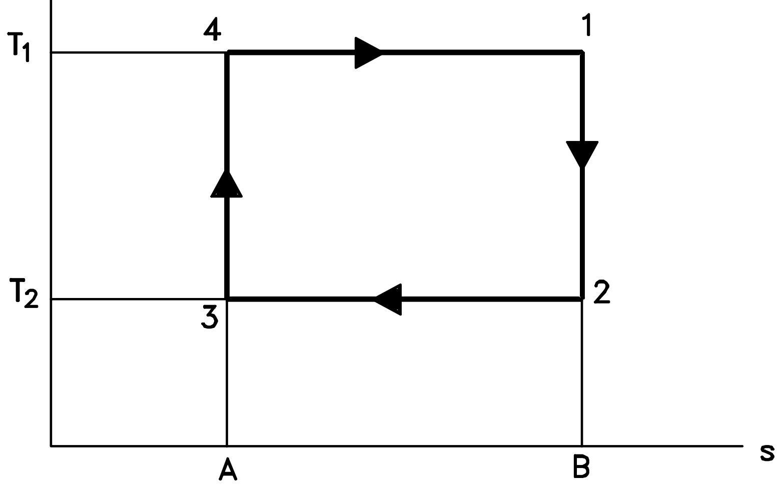
Problem: 3-5

Given: A liquid of specific heat 6.3 $kJ/kg \cdot K$ is heated at approximately constant pressure from 15 to 70 $°C$ by passing it through tubes which are immersed in a furnace. The furnace is heated at 1400 $°C$.

Find: the effectiveness of the heating process when the atmospheric temperature is 10 $°C$.

$$\eta_{Carnot} = \frac{(T_1 - T_2)(s_B - s_A)}{T_1(s_B - s_A)}$$

$$\eta_{Carnot} = 1 - \frac{T_2}{T_1}$$



The increase of exergy of the liquid is:

$$\begin{aligned}
\psi_2 - \psi_1 &= (h_2 - h_1) - T_0(s_2 - s_1) \\
&= 6.3(70 - 15) - 283 \times 6.3 \ln\left(\frac{343}{288}\right) \\
&= 34.7 \; kJ/kg
\end{aligned}$$

The heat rejected by the furnace is equal to the heat supplied to the liquid $(h_2 - h_1)$. If this quantity of heat were supplied to a heat engine operating on the Carnot cycle its thermal efficiency would be:

$$\epsilon = \left(1 - \frac{T_0}{1400 + 273}\right)$$

Therefore work which could be obtained from a heat engine is given by the product of the thermal efficiency and the heat supplied

$$\text{possible work of a heat engine} = (h_2 - h_1)\left(1 - \frac{283}{1673}\right)$$

The possible work of a heat engine is a measure of the loss of exergy of the furnace. That is

$$\begin{aligned} \text{loss of exergy of surroundings} &= 6.3(70 - 15)\left(1 - \frac{283}{1673}\right) \\ &= 288 \ kJ/kg \end{aligned}$$

The effectiveness is

$$\begin{aligned} \epsilon &= \frac{34.7}{288} = 0.121 \\ &= 12.1\% \end{aligned}$$

The very low effectiveness reflects the irreversibility of the transfer of heat through a large temperature difference. If the furnace temperature were much lower the process would be much more effective, although the heat transferred to the liquid would remain the same.