Stirling – Carnot Efficiencies

Recall the Stirling cycle.

We showed the thermal efficiency without regeneration to be:

\[
\eta = \frac{W_{\text{net}}}{Q_{in}} = \frac{W_{12} + W_{23} + W_{34} + W_{41}}{Q_{23} + Q_{34}} = \frac{RT_2 \ln \frac{V_2}{V_1} + RT_3 \ln \frac{V_4}{V_3}}{c_v(T_3 - T_2) + RT_3 \ln \frac{V_4}{V_3}}
\]

With regeneration we use the heat output from the cooling at constant volume process (process 4-1), \(Q_{41}\), to supply the heat input to the heating at constant volume process (process 2-3), \(Q_{23}\). Note that the magnitudes of \(Q_{41}\) and \(Q_{23}\) are equal. Thus the only heat input to the cycle is the heat input \(Q_{34}\) during the isothermal expansion process (process 3-4).
The thermal efficiency of the Stirling cycle with regeneration now becomes:

\[
\eta = \frac{W_{\text{net}}}{Q_{34}} = \frac{R(T_3 - T_2) \ln \frac{V_4}{V_3}}{RT_3 \ln \frac{V_4}{V_3}} = \frac{T_3 - T_2}{T_3}
\]

\[
\eta = 1 - \frac{T_1}{T_3} = 1 - \frac{T_C}{T_H}
\]

Thus the internally and externally reversible Stirling cycle with regeneration has the same efficiency as the Carnot cycle efficiency operating between the same high and low temperature reservoirs.