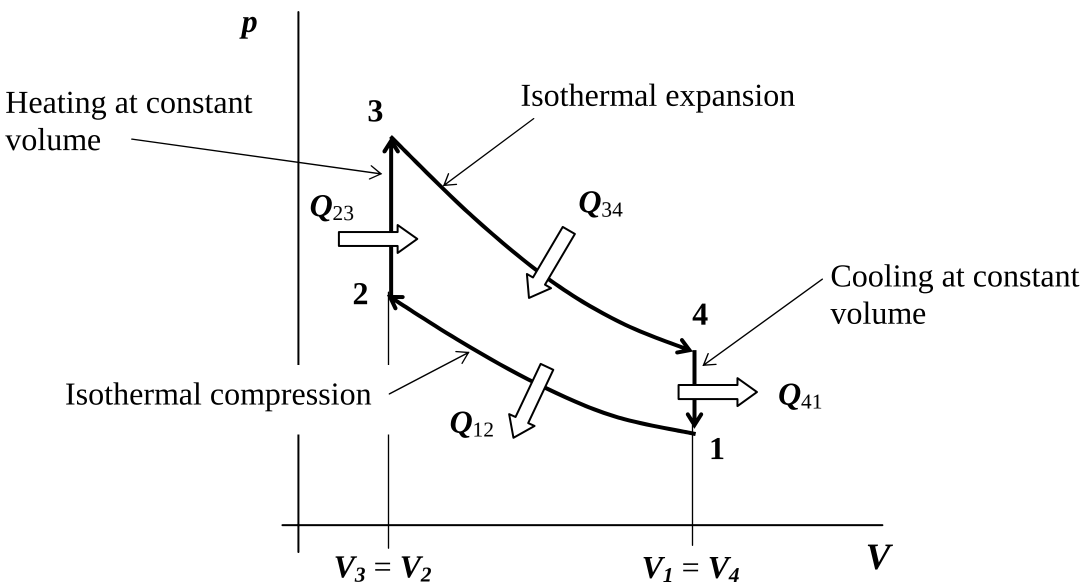
Stirling – Carnot Efficiencies

Recall the Stirling cycle.



We showed the thermal efficiency without regeneration to be:

$$\eta = \frac{W_{net}}{Q_{in}} = \frac{W_{12} + W_{23} + W_{34} + W_{41}}{Q_{23} + Q_{34}} = \frac{RT_1 \ln\frac{V_2}{V_1} + RT_3 \ln\frac{V_4}{V_3}}{c_V (T_3 - T_2) + RT_3 \ln\frac{V_4}{V_3}}$$

$$\eta = \frac{R(T_3 - T_1)\ln\frac{V_1}{V_2}}{c_V (T_3 - T_1) + RT_3 \ln\frac{V_1}{V_2}}$$

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:

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

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

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.