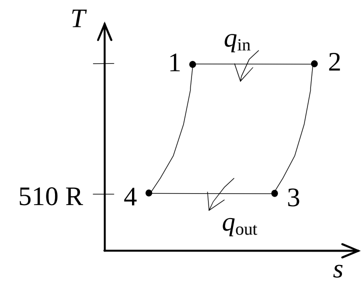
9-80E An ideal Stirling engine with air as the working fluid is considered. The temperature of the source-energy reservoir, the amount of air contained in the engine, and the maximum air pressure during the cycle are to be determined.

Assumptions Air is an ideal gas with constant specific heats.

Properties The properties of air at room temperature are R = 0.3704 psia·ft^3/lbm.R, c_p = 0.240 Btu/lbm·R, c_v = 0.171 Btu/lbm·R, and k = 1.4 (Table A-2E).

Analysis From the thermal efficiency relation,

$$\eta_{\text{th}} = \frac{W_{\text{net}}}{Q_{\text{in}}} = 1 - \frac{T_L}{T_H} \longrightarrow \frac{2.5\text{ Btu}}{6\text{ Btu}} = 1 - \frac{510\text{ R}}{T_H} \longrightarrow T_H = \mathbf{874\ R}$$



State 3 may be used to determine the mass of air in the system,

$$m = \frac{P_3 \boldsymbol{V}_3}{RT_3} = \frac{(10\text{ psia})(0.5\text{ ft}^3)}{(0.3704\text{ psia}\cdot\text{ft}^3/\text{lbm}\cdot\text{R})(510\text{ R})} = \mathbf{0.02647\ lbm}$$

The maximum pressure occurs at state 1,

$$P_1 = \frac{mRT_1}{\boldsymbol{V}_1} = \frac{(0.02647\text{ lbm})(0.3704\text{ psia}\cdot\text{ft}^3/\text{lbm}\cdot\text{R})(874\text{ R})}{0.06\text{ ft}^3} = \mathbf{143\ psia}$$

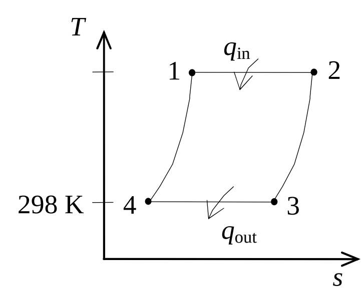
9-81 An ideal Stirling engine with air as the working fluid operates between specified pressure limits. The heat added to the cycle and the net work produced by the cycle are to be determined.

Assumptions Air is an ideal gas with constant specific heats.

Properties The properties of air at room temperature are R = 0.287 kPa·m^3/kg.K, c_p = 1.005 kJ/kg·K, c_v = 0.718 kJ/kg·K, and k = 1.4 (Table A-2a).

Analysis Applying the ideal gas equation to the isothermal process 3-4 gives

$$P_4 = P_3 \frac{\boldsymbol{v}_3}{\boldsymbol{v}_4} = (50\text{ kPa})(12) = 600\text{ kPa}$$



Since process 4-1 is one of constant volume,

$$T_1 = T_4 \left(\frac{P_1}{P_4} \right) = (298\text{ K}) \left(\frac{3600\text{ kPa}}{600\text{ kPa}} \right) = 1788\text{ K}$$

Adapting the first law and work integral to the heat addition process gives

$$q_{\text{in}} = w_{1-2} = RT_1 \ln \frac{\boldsymbol{v}_2}{\boldsymbol{v}_1} = (0.287\text{ kJ/kg}\cdot\text{K})(1788\text{ K})\ln(12) = \mathbf{1275\ kJ/kg}$$

Similarly,

$$q_{\text{out}} = w_{3-4} = RT_3 \ln \frac{\boldsymbol{v}_4}{\boldsymbol{v}_3} = (0.287\text{ kJ/kg}\cdot\text{K})(298\text{ K})\ln\left(\frac{1}{12}\right) = \mathbf{212.5\ kJ/kg}$$

The net work is then

$$w_{\text{net}} = q_{\text{in}} - q_{\text{out}} = 1275 - 212.5 = \mathbf{1063\ kJ/kg}$$