Refrigerant R-134a  \( \rho_1 = \rho_2 \), \( T_1 = -18.8^\circ C \), \( T_2 = 20^\circ C \)

Sat. vapor @ 1

Assume process is reversible and adiabatic.

\[ w = \int \rho \text{d}v = \rho \Delta v \]

\( v_2 = 0.1652 \)  \( (A-11) \)

\( v_1 = 0.1395 \ \text{m}^3/\text{kg} \)  \( (A-12) \)

\( \rho_1 = \rho_2 = 1.4 \ \text{bar} \)

\[ \Rightarrow w = 3.598 \ \text{kJ/kg} \]
The greatest possible efficiency of a power cycle is that of a Carnot cycle operating between the same two temperature reservoirs.

\[ \eta_{th, \text{Carnot}} = 1 - \frac{T_h}{T_i} = 1 - \frac{300}{500} = 0.40 \]

- a) 45\%: impossible
- b) 40\%: possible, but highly unlikely
- c) 35\%: possible
To get minimum area, assume power cycle has the efficiency of a Carnot engine,

\[ \eta_{\text{max}} = 1 - \frac{293}{500} = 41.4 \% \]

\[ \eta = \frac{W_{\text{out}}}{Q_{\text{in}}} \Rightarrow A = \frac{570}{(0.414)(0.315)} \]

\[ \Rightarrow A = 4371 \text{ m}^2 \]
5.54

\[ T_H = 68^\circ F, \ T_c = 35^\circ F \quad Q_r = 30,000 \ Btu/h \]

Actual cost/day: \[ (1 \text{ hp})(1 \text{ kw/ hp})(24 \text{ h}) (0.033 \text{$/kwh}) \]

Actual cost = $1.43/day

The minimum cost would occur if the heat pump had the efficiency of a Carnot engine.

\[ \frac{Q_r}{w} = \frac{T_H}{T_H - T_c} = \frac{528^\circ R}{528 - 445^\circ R} = 16 = \frac{30,000 \text{ Btu/h}}{w} \]

\[ \Rightarrow w = 1,875 \text{ Btu/h} \]

\[ \text{min. cost} = (1,875 \text{ Btu/h})(1 \text{ kw/3413 Btu/h})(24 \text{ h/ day})(0.033 \text{$/kwh}) \]

\[ \Rightarrow \text{min. cost} = $1.05 \text{/day} \]
Methane (CH₄)

\[ p_i = 1 \text{ bar}, \ T_i = 298 \text{ K}, \ p_f = 2 \text{ bar}, \ T_f = T \]

Assuming the process is adiabatic, and the methane acts like an ideal gas,

Eq. 6.23: \( S_2 - S_i = \frac{C_p}{T} dT - \frac{R}{m} \ln \frac{P_2}{P_i} \)

\[ S_2 - S_i = \frac{C_p}{T} dT - 0.3593 \frac{RT}{k_s} \]

\[ C_p = R \left[ 1 + \beta T + \alpha T^2 + \gamma T^3 + \delta T^4 \right] \quad (A-21) \]

\[ S_\text{in} - S_i = \frac{R}{m} \left[ \frac{C_p}{T} + B + \alpha T + \gamma T^2 + \delta T^3 \right] dT - 0.3593 \]

\[ (S_2 - S_i) = 0.519 \left[ 2.401 \left( \ln \frac{T}{298} \right) + 8.738 \left( 10^3 \right) T - 6.607 \left( 10^{-4} \right) (T-298) \right] + 2.002 \left( 10^{-3} \right) (T^2 - 298^2) \]

\[ \Rightarrow 0.3593 \]