1) $\Delta S_{house} = \frac{300}{273+24}$

$$= \frac{100}{99} \text{ kWK}^{-1}$$

$$\left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L}$$

$$Q_L = \frac{T_L}{T_H} Q_H$$

$$= \frac{273+7}{273+24}(300)$$

$$= \frac{28000}{99}$$

$$\Delta S_{air} = \frac{-\frac{2800}{99}}{273+7}$$

$$= -\frac{100}{99} \text{ kWK}^{-1}$$

1) $\Delta S_{gen} = \Delta S_{house} + \Delta S_{air}$

$$= \frac{100}{99} - \frac{100}{99}$$

$$= 0 \geq 0$$

$\therefore$ The heat pump satisfies the second law.

2) $\Delta S_H = \frac{100}{1200}$

$= \frac{1}{12} \text{ kJ K}^{-1}$

$\Delta S_L = \frac{-100}{600}$

$= -\frac{1}{6} \text{ kJ K}^{-1}$

$\Delta S_{gen} = \frac{1}{12} - \frac{1}{6}$

$= -\frac{1}{12} \text{ kJ K}^{-1}$

$\approx -0.0833 \text{ kJ K}^{-1} < 0$

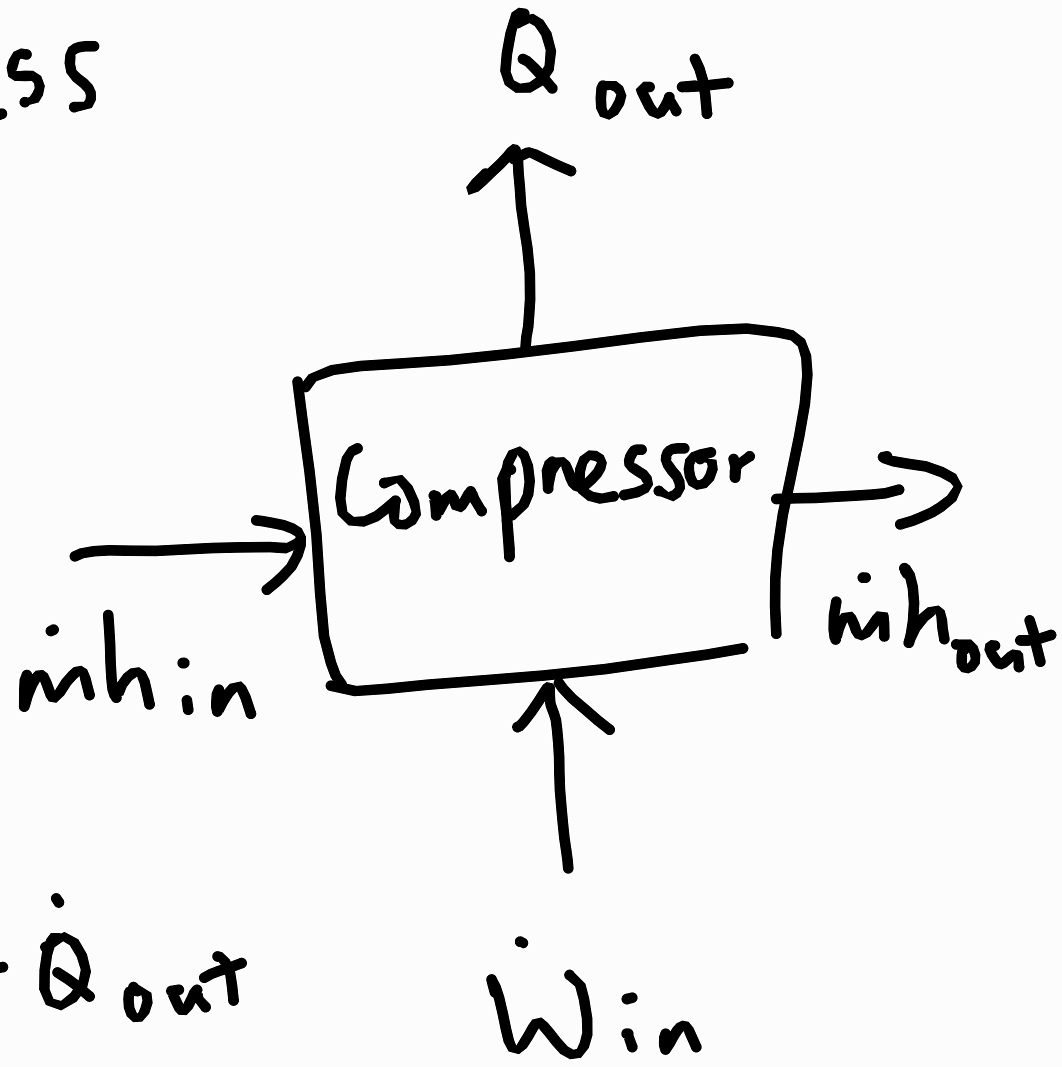
This is an impossible process.

3) Assumptions: Steady state

Steady flow

Air is an ideal gas

Internally reversible process



$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}h_{in} + \dot{W}_{in} = \dot{m}h_{out} + \dot{Q}_{out}$$

$$\dot{W}_{in} = \dot{m}h_{out} - \dot{m}h_{in} + \dot{Q}_{out}$$

$$\dot{W}_{in} = \dot{m}c_p(T_2 - T_1) + \dot{Q}_{out}$$

Since the temperature of the air is constant,

$$\dot{W}_{in} = \dot{Q}_{out}$$

$$\therefore \dot{S}_{air} = \frac{-\dot{Q}_{out}}{25+273}$$

$$= \frac{-15}{298}$$

$$\approx -0.0503 \text{ kW K}^{-1}$$

4) T_{sat} @ 140kPa $= -18.77°C$

↳ isothermal process because of phase change

$$\Delta S_{R134a} = \frac{180}{-18.77+273.15}$$

$$= 0.707602799 \, kJK^{-1}$$

$$\approx 0.7076 \, kJK^{-1}$$

$$\Delta S_c = \frac{-180}{-10+273.15}$$

$$= -\frac{180}{263}$$

$$\approx -0.6844 \, kJK^{-1}$$

$$\Delta S_T = \Delta S_{R134a} + \Delta S_c$$

$$= 0.7076 - 0.6844$$

$$= 0.02319215257 \, kJK^{-1}$$

$$\approx 0.0232 \, kJK^{-1}$$

5a) Finding the mass flow rate of the steel rod,

In one minute:

$$V = 3\left(\frac{(10\times10^{-2})^2}{4}\right)\pi$$

$$= 7.5\pi\times10^{-3}\ m^3$$

$$m = \rho V$$

$$= 7833(7.5\pi\times10^{-3})$$

$$= 184.5607144\ kg$$

$$\approx 184.56\ kg$$

$$\therefore \dot{m} = 184.56\ kg\ min^{-1}$$

$$\dot{Q} = \dot{m}c_p\Delta T$$

$$= 184.56(0.465)(700-30)$$

$$= 57499.89058\ kJ\ min^{-1}$$

$$= 958.3315096\ kW$$

$$\approx 958.3\ kW$$

5b) $\dot{S}_{steel} = \dot{m}c\ln\left(\frac{T_2}{T_1}\right)$

$= 184.56(0.465)\ln\left(\frac{700+273}{30+273}\right)$

$= 100.1228668\,kJ\,K^{-1}\,min^{-1}$

$= 1.668714447\,kJ\,K^{-1}s^{-1}$

$\dot{S}_{oven} = \frac{-\dot{Q}}{T}$

$= \frac{-958.3}{273+900}$

$= -0.8169919093\,kJ\,K^{-1}s^{-1}$

$\dot{S}_{gen} = 1.668714447 - 0.8169919093$

$= 0.8517225372\,kJ\,K^{-1}s^{-1}$

$\approx 0.85\,kJ\,K^{-1}s^{-1}$