

Energy Systems 1 , Fall 2009 Exam 1

1. An ideal Carnot Cycle operates with 2 lbs of water. The cycle high pressure is 200 psi. The cycle low pressure is 5 psi. During the high pressure process the water is heated, changing from a saturated liquid to a saturated vapor. Determine the work done during each process and the cycle efficiency. Sketch a property diagram of the cycle.
2. A flow of $4 \text{ m}^3/\text{min}$ of CO_2 at 300 C is mixed with a flow of 2 kg of air at 100 C in an insulated vessel. Pressure is constant at 100 kPa during the mixing process. Assume the properties of CO_2 and air can be obtained using the ideal gas model. Determine the entropy generated by the process?
3. A non-ideal power cycle operates with an efficiency of 40% and rejects heat at 35 C . The power cycle is used to drive a non ideal refrigeration cycle which has a coefficient of performance as a refrigerator of 5 and absorbs 200 kJ at 15 C . How much heat is rejected by the refrigeration cycle and input into the power cycle? What is the lowest possible temperature for heat input to the power cycle and heat rejection by the refrigeration cycle?

1.

Pt	T	p	u	h	s
1	381.8	200	354.78	355.46	.54379
2		200	1114.1	1198.8	1.546
3	162.18				5
4	162.18				5

$$Q_{12} = \Delta U + W$$

$$Q_{12} = m \times (h_2 - h_1)$$

$$Q_{12} = 2 \times (1198.8 - 355.46) = 1686.68$$

$$W_{12} = Q_{12} - \Delta U$$

$$W_{12} = 1686.68 - 2 \times (1114.1 - 354.78) = 168.04 \text{ Btu}$$

$$W_{12 \text{ alternate}} = m \times p_1 \times (v_2 - v_1)$$

$$W_{12 \text{ alternate}} = 2 \times 200 \times (2.288 - .01839) \times \frac{144}{778} = 168 \text{ Btu}$$

$$Q_{23} = 0$$

$$W_{23} = \Delta U_{23} = 2 \times (1114.1 - 890.18)$$

$$W_{23} = 447.84 \text{ Btu}$$

$$Q_{34} = m \times (h_4 - h_3) = 2 \times (1246.62 - 322.28) = 1246.6$$

$$W_{34} = Q_{34} - m \times (u_3 - u_4)$$

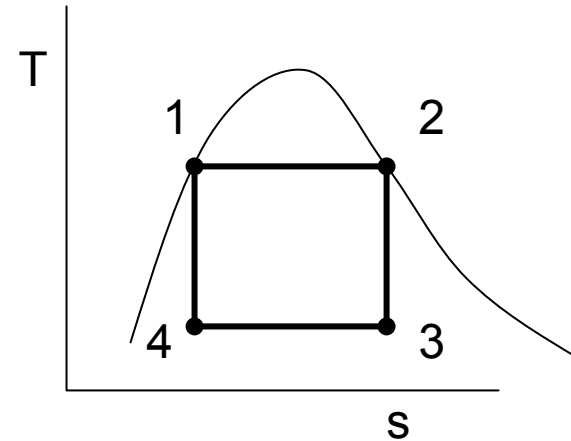
$$W_{34} = 1246.6 - 2 \times (890.18 - 309.22)$$

$$W_{34} = -84.68 \text{ Btu}$$

$$W_{31} = \Delta U_{31}$$

$$W_{41} = 2 \times (354.78 - 309.22) = -91.12 \text{ Btu}$$

$$\sum W = 168.04 + 447.84 - 84.68 - 91.12 = 440.04 \text{ Btu}$$



$$\eta_{\text{cycle}} = \frac{T_H - T_l}{T_H} = \frac{381.8 - 162.18}{381.8 + 459.69} = .26$$

$$x_3 = \frac{s_2 - s_f}{s_{fg}} = \frac{1.546 - .23488}{1.60894} = .815$$

$$u_3 = 130.17 + .815 \times (1062.7 - 130.17)$$

$$u_3 = 890.18$$

$$h_3 = 130.18 + .815 \times (1000.5)$$

$$h_3 = 945.59$$

$$x_4 = \frac{s_1 - s_f}{s_{fg}} = \frac{.54379 - .23488}{1.60894} = .192$$

$$u_4 = 130.17 + .192 \times (1062.7 - 130.17)$$

$$u_4 = 309.22$$

$$h_4 = 130.18 + .192 \times (1000.5)$$

$$h_4 = 322.28$$

2.

$$m = \frac{pV}{RT} = \frac{100 \times 4}{\frac{8.314}{44} (300 + 273.15)} = 3.69 \text{ kg}$$

$$m_1 + m_2 = m_3$$

$$m_1 h_1 + m_2 h_2 = m_3 h_3$$

$$m_1 c_p T_1 + m_2 c_p T_2 = m_1 c_p T_3 + m_3 c_p T_3$$

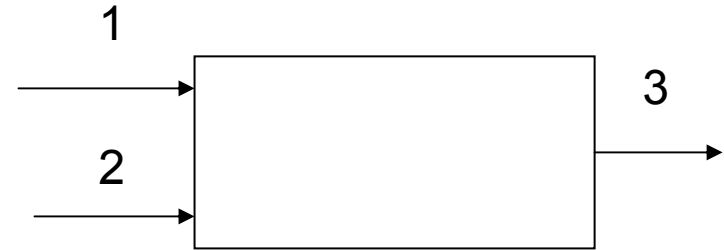
$$3.69 \times .846 \times 300 + 2 \times 1.005 \times 100 = 3.69 \times .846 \times T_3 + 2 \times 1.005 \times T_3$$

$$T_3 = 221.67 \text{ C}$$

$$\Delta S_{\text{CO}_2} = m \left(c_p \ln \left(\frac{T_3}{T_1} \right) \right) = 3.69 \times .846 \times \ln \left(\frac{494.82}{573.15} \right) = -.4588 \text{ kJ/kgK}$$

$$\Delta S_{\text{air}} = m \left(c_p \ln \left(\frac{T_3}{T_2} \right) \right) = 2 \times 1.005 \times \ln \left(\frac{494.82}{371.15} \right) = +.5672 \text{ kJ/kgK}$$

$$S_{\text{generated}} = \Delta S_{\text{CO}_2} + \Delta S_{\text{air}} = -.4588 + .5672 = .1084 \text{ kJ/kgK}$$



3.

$$\text{COP}_{\text{ref}} = 5 = \frac{Q_L}{Q_H - Q_L} = \frac{200}{Q_H - 200}$$

$$Q_{H, \text{ref}} = 240 \text{ kJ}$$

$$W_{\text{ref}} = 40 = W_{\text{power}}$$

$$\eta_{\text{power}} = \frac{W_{\text{power}}}{Q_H} = \frac{40}{Q_H}$$

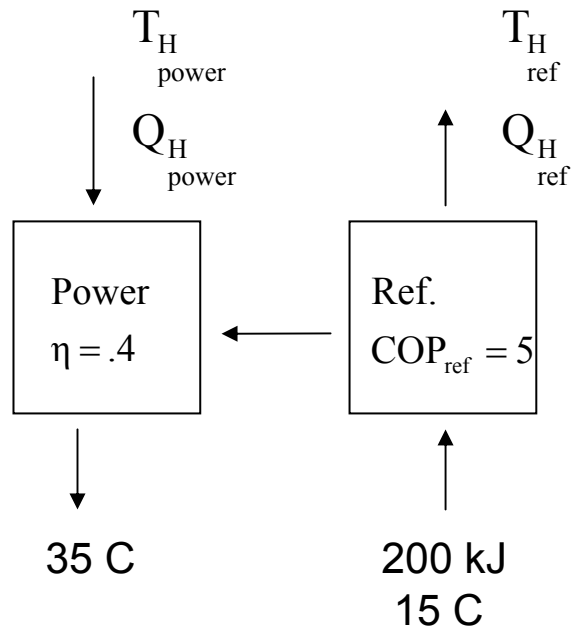
$$Q_{H, \text{power}} = 100 \text{ kJ}$$

$$\text{COP}_{\text{ideal}}^{\text{red}} = \frac{T_L}{T_H - T_L} = \frac{288}{T_H - 288} = 5$$

$$T_{H, \text{ref}} = 345.6 \text{ K}, 72.6 \text{ C}$$

$$\eta_{\text{ideal}}^{\text{power}} = \frac{T_H - T_L}{T_H} = \frac{T_H - 308}{T_H}$$

$$T_{H, \text{power}} = 513 \text{ K}, 240 \text{ C}$$



Grade No

70 1

60

50 2

40 1

30 3

20 7

10 3

0 1

ave 30.2

1.

high pressure turbine

$$w = m \times (h_1 - h_2)$$

medium pressure turbine

$$w = (m - mx) \times (h_2 - h_3)$$

low pressure turbine

$$w = (m - mx - my) \times (h_3 - h_4)$$

boiler

$$q = m \times (h_1 - h_2)$$

condenser

$$Q + (m - mx) \times h_6 = (m - mx - my) \times h_4 + my \times h_7$$

low pressure heater

$$mx \times (h_3 - h_7) = (m - mx) \times (h_8 - h_7)$$

high pressure heater

$$m \times (h_2 - h_9) = (m - mx) \times (h_{10} - h_9)$$

mixing

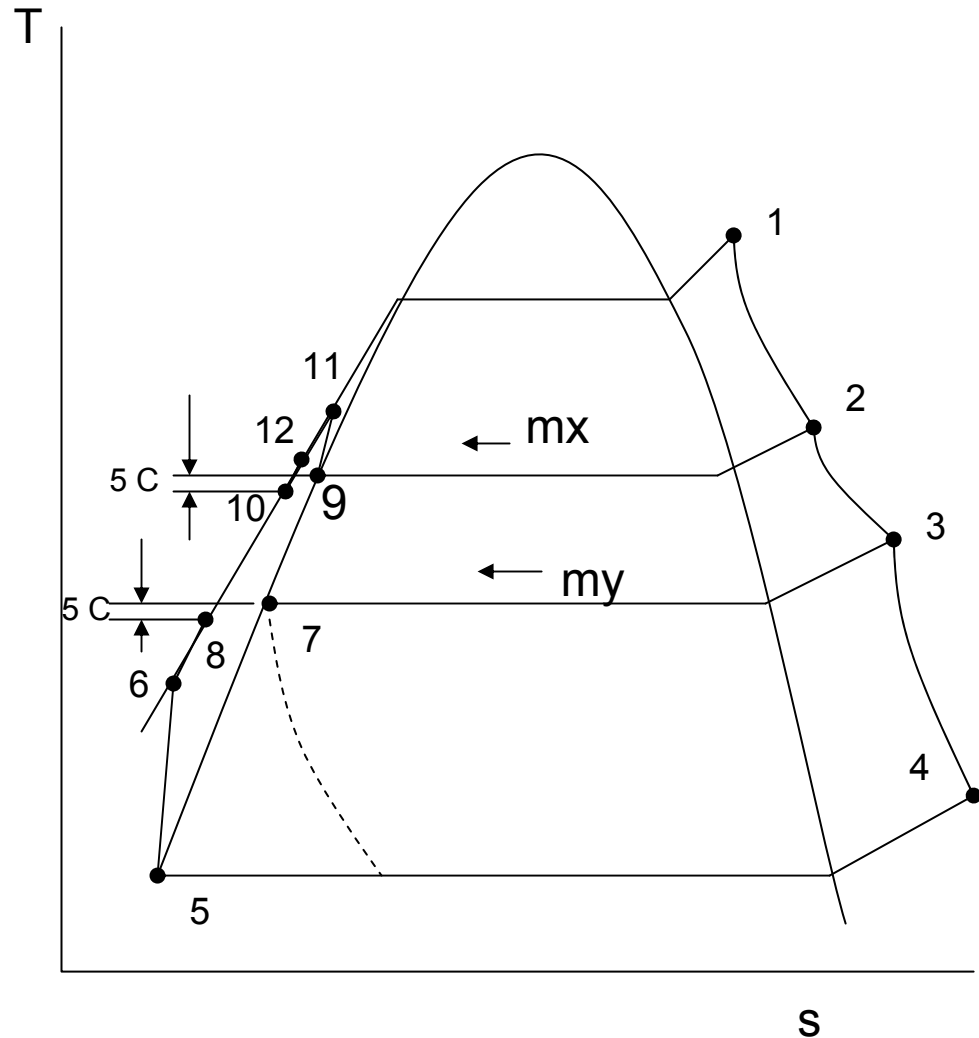
$$mx \times h_{11} + (m - mx) \times h_{10} = m \times h_{12}$$

main pump

$$w = (m - mx) \times (h_6 - h_5)$$

condensate pump

$$w = mx \times (h_{11} - h_9)$$



2.

$$@ 300 \text{ K } (v_r)_1 = 621.2, u_1 = 214.07$$

$$v_1 = \frac{RT}{p} = \frac{.287 \times 300}{100} = .861$$

$$v_2 = .861/14.843 = .058$$

$$@ 1800 \text{ K}, (v_r)_3 = 3.994, u_3 = 1487.2, h_3 = 2003.3$$

$$\frac{v_1}{v_2} = \frac{(v_r)_1}{(v_r)_2}$$

$$(v_r)_2 = 621.2/14.843 = 41.851$$

$$@ (v_r)_2 = 41.851, u_2 = 624.95, h_2 = 866.08, T_2 = 840$$

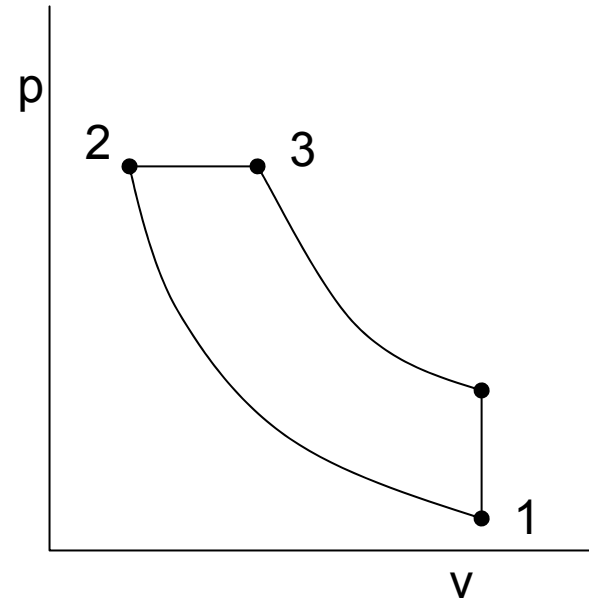
$$v_3 = v_2 \frac{T_3}{T_2} = .058 \times \frac{1800}{840} = .1243$$

$$w_{12} = u_2 - u_1 = 624.95 - 214.07 = 410.88$$

$$q_{23} = h_3 - h_2 = 2003.3 - 866.08 = 1137.22$$

$$w_{23} = q_{23} - (u_3 - u_2) = 1137.22 - (1487.2 - 624.95)$$

$$w_{23} = 274.95$$



Grade No

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80

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30 5

ave 52