MAK 212 - TERMODİNAMİK

CRN: 21688, 21689, 21690, 21691, 21692

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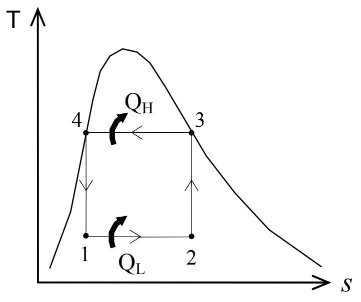
ÖDEV 10

10-5 (a) Noting that $T_H = T_{sat\,@\,800\,kPa} = 32.74°C = 305.7$ K and $T_L = T_{sat\,@\,140\,kPa} = -21.91°C = 251.1$ K,

$$\mathrm{COP}_{R,C} = \frac{1}{T_H / T_L - 1} = \frac{1}{(305.7K)/(251.1K) - 1} = \mathbf{4.60}$$



(b) Process 4-1 is isentropic, and thus

$$s_1 = s_4 = \left(s_f + x_4 s_{fg}\right)_{@800kPa} = 0.3459 + (0.05)(0.9066 - 0.3459)$$
$$= 0.3739 kJ/kg\cdot K$$

$$x_1 = \left(\frac{s_1 - s_f}{s_{fg}}\right)_{@140kPa} = \frac{0.3739 - 0.1055}{0.9322 - 0.1055} = \mathbf{0.325}$$

(c) Remembering that on a T-s diagram the area enclosed represents the net work, and $s_3 = s_{sat\,@\,800\,kPa} = 0.9066$ kJ/kg·K,

$$w_{net,in} = (T_H - T_L)(s_3 - s_4)$$
$$= [32.74 - (-21.91)K](0.9066 - 0.3739) kJ/kg\cdot K$$
$$= \mathbf{29.1 kJ/kg}$$

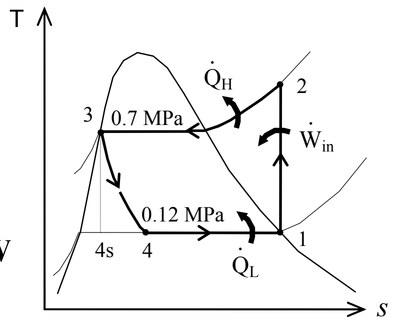
10-13 (a) In an ideal vapor-compression refrigeration cycle, the compression process is isentropic, the refrigerant enters the compressor as a saturated vapor at the evaporator pressure, and leaves the condenser as saturated liquid at the condenser pressure. From the refrigerant tables,

$$\left.\begin{array}{l} P_1 = 120kPa \\ sat.vapor \end{array}\right\} \begin{array}{l} h_1 = h_{g@120kPa} = 233.86 kJ/kg \\ s_1 = s_{g@120kPa} = 0.9354 kJ/kg\cdot K \end{array}$$

$$\left.\begin{array}{l} P_2 = 0.7MPa \\ s_2 = s_1 \end{array}\right\} h_2 = 270.22 kJ/kg \; (T_2 = 34.6^\circ C)$$

$$\left.\begin{array}{l} P_3 = 0.7MPa \\ sat.liquid \end{array}\right\} h_3 = h_{f@0.7MPa} = 86.78 kJ/kg$$

$$h_4 \cong h_3 = 86.78 kJ/kg \; (throttling)$$



Then the rate of heat removal from the refrigerated space and the power input to the compressor are determined from

$$\dot{Q}_L = \dot{m}(h_1 - h_4) = (0.05 kg/s)(233.86 - 86.78) kJ/kg = \mathbf{7.35 kW}$$

and

$$\dot{W}_{in} = \dot{m}(h_2 - h_1) = (0.05 kg/s)(270.22 - 233.86) kJ/kg = \mathbf{1.82 kW}$$

(b) The rate of heat rejection to the environment is determined from

$$\dot{Q}_H = \dot{Q}_L + \dot{W}_{in} = 7.35 + 1.82 = \mathbf{9.17 kW}$$

(c) The COP of the refrigerator is determined from its definition,

$$\mathrm{COP}_R = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{7.35 \text{ kW}}{1.82 \text{ kW}} = \mathbf{4.04}$$

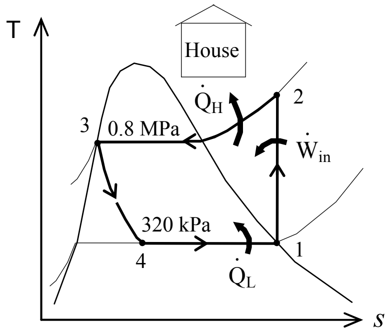
10-28 In an ideal vapor-compression refrigeration cycle, the compression process is isentropic, the refrigerant enters the compressor as a saturated vapor at the evaporator pressure, and leaves the condenser as saturated liquid at the condenser pressure. From the refrigerant tables,

$$\left.\begin{array}{l} P_1 = 320 kPa \\ sat.vapor \end{array}\right\} \begin{array}{l} h_1 = h_{g@320kPa} = 248.66 kJ/kg \\ s_1 = s_{g@320kPa} = 0.9177 kJ/kg \cdot K \end{array}$$

$$\left.\begin{array}{l} P_2 = 0.8 MPa \\ s_2 = s_1 \end{array}\right\} h_2 = 267.58 kJ/kg \; (T_2 = 34.5^\circ C)$$

$$\left.\begin{array}{l} P_3 = 0.8 MPa \\ sat.liquid \end{array}\right\} h_3 = h_{f@0.8MPa} = 93.42 kJ/kg$$

$$h_4 \cong h_3 = 93.42 kJ/kg \; (throttling)$$



The mass flow rate of the refrigerant and the power input to the compressor are determined from

$$\dot{m} = \frac{\dot{Q}_H}{q_H} = \frac{\dot{Q}_H}{h_2 - h_3} = \frac{75{,}000/3{,}600 kJ/s}{(267.58 - 93.42) kJ/kg} = 0.120 kg/s$$

and

$$\dot{W}_{in} = \dot{m}(h_2 - h_1) = (0.120 kg/s)(267.58 - 248.66) kJ/kg = \mathbf{2.27kW}$$

The electrical power required without the heat pump is

$$\dot{W}_e = \dot{Q}_H = 75{,}000/3{,}600 kJ/s = 20.83 kW$$

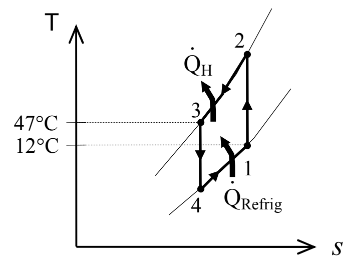
Thus,

$$\dot{W}_{saved} = \dot{W}_e - \dot{W}_{in} = 20.83 - 2.27 = \mathbf{18.56kW}$$

10-49 (a) We assume air to be an ideal gas with variable specific heats. We also assume both the turbine and the compressor to be isentropic, the turbine inlet temperature to be the temperature of the surroundings, and the compressor inlet temperature to be the temperature of the refrigerated space. From the air table,

$$T_1 = 285 K \longrightarrow \begin{array}{l} h_1 = 285.14 kJ/kg \\ P_{r_1} = 1.1584 \end{array}$$

$$T_1 = 320 K \longrightarrow \begin{array}{l} h_3 = 320.29 kJ/kg \\ P_{r_3} = 1.7375 \end{array}$$



Thus,

$$P_{r_2} = \frac{P_2}{P_1} P_{r_1} = \left(\frac{250}{50}\right)(1.1584) = 5.792 \longrightarrow \begin{array}{l} T_2 = 450.4 K \\ h_2 = 452.17 kJ/kg \end{array}$$

$$P_{r_4} = \frac{P_4}{P_3} P_{r_3} = \left(\frac{50}{250}\right)(1.7375) = 0.3475 \longrightarrow \begin{array}{l} T_4 = 201.8 K \\ h_4 = 201.76 kJ/kg \end{array}$$

Then the rate of refrigeration is

$$\dot{Q}_{refrig} = \dot{m}(q_L) = \dot{m}(h_1 - h_4) = (0.08 kg/s)(285.14 - 201.76) kJ/kg = \mathbf{6.67kW}$$

(b) The net power input is determined from

$$\dot{W}_{net,in} = \dot{W}_{comp,in} - \dot{W}_{turb,out}$$

where

$$\dot{W}_{comp,in} = \dot{m}(h_2 - h_1) = (0.08 kg/s)(452.17 - 285.14) kJ/kg = 13.36 kW$$

$$\dot{W}_{turb,out} = \dot{m}(h_3 - h_4) = (0.08 kg/s)(320.29 - 201.76) kJ/kg = 9.48 kW$$

Thus, $\dot{W}_{net,in} = 13.36 - 9.48 = \mathbf{3.88kW}$

(c) The COP of this ideal gas refrigeration cycle is determined from

$$COP_R = \frac{\dot{Q}_L}{\dot{W}_{net,in}} = \frac{6.61kW}{3.88kW} = \mathbf{1.72}$$

10-81 (a) We assume helium to be an ideal gas with constant specific heats, $C_p = 5.1926$ kJ/kg·K and $k = 1.667$. The temperature of the helium at the turbine inlet is determined from an energy balance on the regenerator,

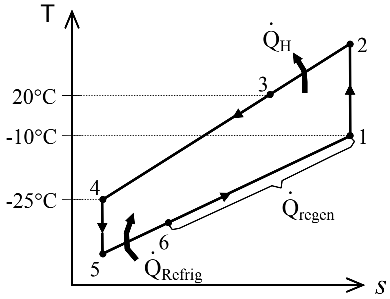
$$\dot{Q}^{\nearrow 0} - \dot{W}^{\nearrow 0} = \sum \dot{m}_e h_e - \sum \dot{m}_i h_i \longrightarrow \dot{m}(h_3 - h_4) = \dot{m}(h_1 - h_6)$$

or,

$$\dot{m}C_p(T_3 - T_4) = \dot{m}C_p(T_1 - T_6) \longrightarrow T_3 - T_4 = T_1 - T_6$$

Thus,

$$T_4 = T_3 - T_1 + T_6 = 20^\circ C - (-10^\circ C) + (-25^\circ C) = -5^\circ C = 268K$$



(b) From the isentropic relations,

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{(k-1)/k} = (263K)(3)^{0.667/1.667} = 408.2K = 135.2^\circ C$$

$$T_5 = T_4\left(\frac{P_5}{P_4}\right)^{(k-1)/k} = (268K)\left(\frac{1}{3}\right)^{0.667/1.667} = 172.7K = -100.3^\circ C$$

Then the COP of this ideal gas refrigeration cycle is determined from

$$COP_R = \frac{q_L}{w_{net,in}} = \frac{q_L}{w_{comp,in} - w_{turb,out}} = \frac{h_6 - h_5}{(h_2 - h_1) - (h_4 - h_5)}$$

$$= \frac{T_6 - T_5}{(T_2 - T_1) - (T_4 - T_5)} = \frac{-25^\circ C - (-100.3^\circ C)}{[135.2 - (-10)]^\circ C - [-5 - (-100.3)]^\circ C} = \mathbf{1.51}$$

(c) The net power input is determined from

$$\dot{W}_{net,in} = \dot{W}_{comp,in} - \dot{W}_{turb,out} = \dot{m}[(h_2 - h_1) - (h_4 - h_5)] = \dot{m}C_p[(T_2 - T_1) - (T_4 - T_5)]$$

$$= (0.3kg/s)(5.4926kJ/kg\cdot^\circ C)([135.2 - (-10)] - [-5 - (-100.3)]) = \mathbf{77.7kW}$$