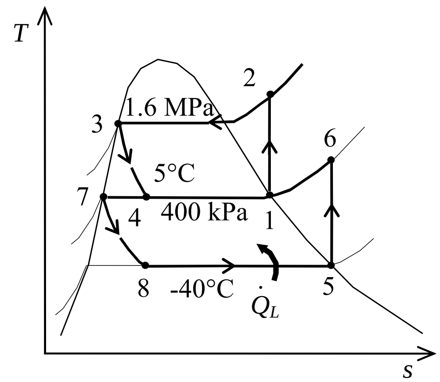
11-65 A two-stage vapor-compression refrigeration system with refrigerant-134a as the working fluid is considered. The process with the greatest exergy destruction is to be determined.

Assumptions **1** Steady operating conditions exist. **2** Kinetic and potential energy changes are negligible.

Analysis From Prob. 11-55 and the water and refrigerant tables (Tables A-4, A-5, A-6, A-11, A-12, and A-13),

$s_1 = s_2 = 9.0249 \text{ kJ/kg}\cdot\text{K}$
$s_3 = 2.3435 \text{ kJ/kg}\cdot\text{K}$
$s_4 = 3.0869 \text{ kJ/kg}\cdot\text{K}$
$s_5 = s_6 = 0.96866 \text{ kJ/kg}\cdot\text{K}$
$s_7 = 0.24757 \text{ kJ/kg}\cdot\text{K}$
$s_8 = 0.27423 \text{ kJ/kg}\cdot\text{K}$
$\dot{m}_R = 0.1235 \text{ kg/s}$
$\dot{m}_w = 0.01523 \text{ kg/s}$
$q_L = h_5 - h_8 = 161.92 \text{ kJ/kg}$
$q_H = h_2 - h_3 = 4225.0 \text{ kJ/kg}$
$T_L = -30°\text{C} = 243 \text{ K}$
$T_H = 30°\text{C} = 303 \text{ K}$
$T_0 = 30°\text{C} = 303 \text{ K}$



The exergy destruction during a process of a stream from an inlet state to exit state is given by

$$x_{\text{dest}} = T_0 s_{\text{gen}} = T_0\left(s_e - s_i - \frac{q_{\text{in}}}{T_{\text{source}}} + \frac{q_{\text{out}}}{T_{\text{sink}}}\right)$$

Application of this equation for each process of the cycle gives

$$\dot{X}_{\text{destroyed},23} = \dot{m}_w T_0\left(s_3 - s_2 + \frac{q_H}{T_H}\right)$$
$$= (0.01523)(303\text{ K})\left(2.3435 - 9.0249 + \frac{4225.0}{303}\right) = 33.52 \text{ kJ/s}$$

$$\dot{X}_{\text{destroyed},34} = \dot{m}_{\text{w}} T_0 (s_4 - s_3) = (0.01523)(303)(3.0869 - 2.3435) = 3.43 \text{ kJ/s}$$

$$\dot{X}_{\text{destroyed},78} = \dot{m}_{\text{R}} T_0 (s_8 - s_7) = (0.1235)(303)(0.27423 - 0.24757) = 0.996 \text{ kJ/s}$$

$$\dot{X}_{\text{destroyed},85} = \dot{m}_{\text{R}} T_0\left(s_5 - s_8 - \frac{q_L}{T_L}\right)$$
$$= (0.1235)(303)\left(0.96866 - 0.27423 - \frac{161.92}{243}\right) = 1.05 \text{ kJ/s}$$

$$\dot{X}_{\text{destroyed, heat exch}} = T_0\left[\dot{m}_{\text{w}}(s_1 - s_4) + \dot{m}_{\text{R}}(s_7 - s_6)\right]$$
$$= (303)\left[(0.01523)(9.0249 - 3.0869) + (0.1235)(0.24757 - 0.96866)\right] = 0.417 \text{ kJ/s}$$

For isentropic processes, the exergy destruction is zero:

$$\dot{X}_{\text{destroyed},12} = 0$$
$$\dot{X}_{\text{destroyed},56} = 0$$

Note that heat is absorbed from a reservoir at -30°C (243 K) and rejected to a reservoir at 30°C (303 K), which is also taken as the dead state temperature. Alternatively, one may use the standard 25°C (298 K) as the dead state temperature, and perform the calculations accordingly. The greatest exergy destruction occurs in the condenser.