5.43 A refrigeration cycle operating between two reservoirs receives energy $Q_c$ from a cold reservoir at $T_c = 275$ K and rejects energy $Q_h$ to a hot reservoir at $T_h = 315$ K. For each of the following cases determine whether the cycle operates *reversibly*, operates *irreversibly*, or is *impossible*:

(a) $Q_c = 1000$ kJ, $W_{cycle} = 80$ kJ.
(b) $Q_c = 1200$ kJ, $Q_h = 2000$ kJ.
(c) $Q_h = 1575$ kJ, $W_{cycle} = 200$ kJ.
(d) $\beta = 6$.

**KNOWN:** A refrigeration cycle operates between two reservoirs with specified temperatures.

**FIND:** Whether each of four cycles operates *reversibly*, operates *irreversibly*, or is *impossible*.

**SCHEMATIC AND GIVEN DATA:**

**ENGINEERING MODEL:**
1. The control volume defined by the dashed line on the accompanying diagram undergoes a refrigeration cycle.

**ANALYSIS:**
The maximum coefficient of performance for a refrigeration cycle operating between two reservoirs is

$$\beta_{max} = \frac{T_c}{T_h - T_c} = \frac{275 \text{ K}}{315 \text{ K} - 275 \text{ K}} = 6.875$$
PROBLEM 5.43 (Continued)

Coefficient of performance for any refrigeration cycle is

$$\beta = \frac{Q_C}{W_{cycle}}$$

(a) Given $Q_C = 1000 \, \text{kJ}$, $W_{cycle} = 80 \, \text{kJ}$, the coefficient of performance determined using these energy data is

$$\beta = \frac{1000 \, \text{kJ}}{80 \, \text{kJ}} = 12.5$$

Since $\beta = 12.5 > \beta_{\text{max}} = 6.875$, the cycle is impossible.

(b) Given $Q_C = 1200 \, \text{kJ}$, $Q_H = 2000 \, \text{kJ}$, cycle work can be determined from

$$W_{cycle} = Q_H - Q_C = 2000 \, \text{kJ} - 1200 \, \text{kJ} = 800 \, \text{kJ}$$

The coefficient of performance determined using these energy data is

$$\beta = \frac{1200 \, \text{kJ}}{800 \, \text{kJ}} = 1.5$$

Since $\beta = 1.5 < \beta_{\text{max}} = 6.875$, the cycle operates irreversibly.

(c) Given $Q_H = 1575 \, \text{kJ}$, $W_{cycle} = 200 \, \text{kJ}$, heat transfer associated with the cold reservoir can be determined from

$$W_{cycle} = Q_H - Q_C \rightarrow Q_C = Q_H - W_{cycle} = 1575 \, \text{kJ} - 200 \, \text{kJ} = 1375 \, \text{kJ}$$

The coefficient of performance determined using these energy data is

$$\beta = \frac{1375 \, \text{kJ}}{200 \, \text{kJ}} = 6.875$$

Since $\beta = \beta_{\text{max}} = 6.875$, the cycle operates reversibly.

(d) Given $\beta = 6$, the cycle is irreversible.

Since $\beta = 6 < \beta_{\text{max}} = 6.875$, the cycle operates irreversibly.