6-97 A chilled-water heat-exchange unit is designed to cool air by water. The maximum water outlet temperature is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work interactions. **4** Heat loss from the device to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **5** Air is an ideal gas with constant specific heats at room temperature.

Properties The gas constant of air is 0.287 kPa.m^3/kg.K (Table A-1). The constant pressure specific heat of air at room temperature is c_p = 1.005 kJ/kg·°C (Table A-2*a*). The specific heat of water is 4.18 kJ/kg·K (Table A-3).

Analysis The water temperature at the heat exchanger exit will be maximum when all the heat released by the air is picked up by the water. First, the inlet specific volume and the mass flow rate of air are

$$\boldsymbol{v}_1 = \frac{RT_1}{P_1} = \frac{(0.287 \text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(303 \text{ K})}{100 \text{ kPa}} = 0.8696 \text{ m}^3/\text{kg}$$

$$\dot{m}_a = \frac{\dot{\boldsymbol{V}}_1}{\boldsymbol{v}_1} = \frac{5 \text{ m}^3/\text{s}}{0.8696 \text{ m}^3/\text{kg}} = 5.750 \text{ kg/s}$$

We take the entire heat exchanger as the system, which is a control volume. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance (*for each fluid stream*):

$$\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta\dot{m}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0 \rightarrow \dot{m}_{\text{in}} = \dot{m}_{\text{out}} \rightarrow \dot{m}_1 = \dot{m}_3 = \dot{m}_a \text{ and } \dot{m}_2 = \dot{m}_4 = \dot{m}_w$$

Energy balance (for the entire heat exchanger):

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer}\\\text{by heat, work, and mass}}} = \underbrace{\Delta\dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,}\\\text{potential, etc. energies}}} = 0$$

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

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{m}_4 h_4 \quad (\text{since } \dot{Q} = \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two,

$$\dot{m}_a (h_1 - h_3) = \dot{m}_w (h_4 - h_2)$$

$$\dot{m}_a c_{p,a} (T_1 - T_3) = \dot{m}_w c_{p,w} (T_4 - T_2)$$

Solving for the exit temperature of water,

$$T_4 = T_2 + \frac{\dot{m}_a c_{p,a} (T_1 - T_3)}{\dot{m}_w c_{p,w}} = 8°\text{C} + \frac{(5.750 \text{ kg/s})(1.005 \text{ kJ/kg}\cdot°\text{C})(30-18)°\text{C}}{(2 \text{ kg/s})(4.18 \text{ kJ/kg}\cdot°\text{C})} = \mathbf{16.3°C}$$