14-82 Air is cooled and dehumidified at constant pressure. The amount of water removed from the air and the rate of cooling are to be determined.

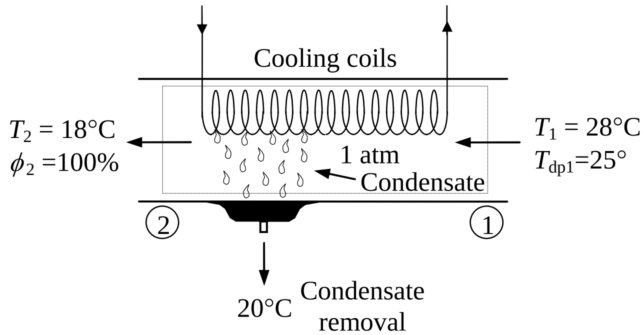
Assumptions **1** This is a steady-flow process and thus the mass flow rate of dry air remains constant during the entire process $(\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a)$. **2** Dry air and water vapor are ideal gases. **3** The kinetic and potential energy changes are negligible.

Properties The inlet and the exit states of the air are completely specified, and the total pressure is 1 atm. The properties of the air at various states are determined from the psychrometric chart (Figure A-31) to be

$$h_1 = 79.6 \text{ kJ/kg dry air}$$
$$\omega_1 = 0.0202 \text{ kg H}_2\text{O/kg dry air}$$
$$\boldsymbol{v}_1 = 0.881 \text{ m}^3\text{/kg dry air}$$

and

$$\phi_2 = 1.0$$
$$h_2 = 51.0 \text{ kJ/kg dry air}$$
$$\omega_2 = 0.0130 \text{ kg H}_2\text{O/kg dry air}$$



Also,

$$h_w \cong h_{f\,@\,20°\text{C}} = 83.915 \text{ kJ/kg} \qquad \text{(Table A-4)}$$

Analysis The amount of moisture in the air decreases due to dehumidification ($\omega_2 < \omega_1$). The mass flow rate of air is

$$\dot{m}_{a1} = \frac{\dot{\boldsymbol{V}}_1}{\boldsymbol{v}_1} = \frac{(10{,}000/3600) \text{ m}^3/\text{s}}{0.881 \text{ m}^3/\text{kg dry air}} = 3.153 \text{ kg/s}$$

Applying the water mass balance and energy balance equations to the combined cooling and dehumidification section,

Water Mass Balance:

$$\sum \dot{m}_{w,i} = \sum \dot{m}_{w,e} \longrightarrow \dot{m}_{a1}\omega_1 = \dot{m}_{a2}\omega_2 + \dot{m}_w$$

$$\dot{m}_w = \dot{m}_a(\omega_1 - \omega_2) = (3.153 \text{ kg/s})(0.0202 - 0.0130) = \mathbf{0.0227 \text{ kg/s}}$$

Energy Balance:

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \Delta\dot{E}_{\text{system}}^{\;\nearrow 0 \text{ (steady)}} = 0$$
$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$
$$\sum \dot{m}_i h_i = \dot{Q}_{out} + \sum \dot{m}_e h_e$$
$$\dot{Q}_{\text{out}} = \dot{m}_{a1}h_1 - (\dot{m}_{a2}h_2 + \dot{m}_w h_w) = \dot{m}_a(h_1 - h_2) - \dot{m}_w h_w$$

$$\dot{Q}_{\text{out}} = (3.153 \text{ kg/s})(79.6 - 51.0)\text{kJ/kg} - (0.02227 \text{ kg/s})(83.915 \text{ kJ/kg})$$
$$= \mathbf{88.3 \text{ kW}}$$