14-73 Saturated humid air at a specified state is heated to a specified temperature. The relative humidity at the exit and the rate of heat transfer 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.

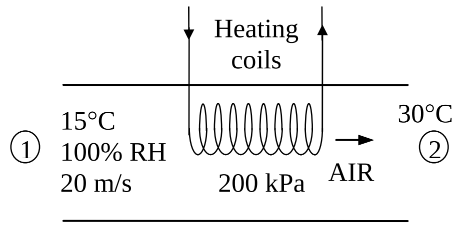
Analysis The amount of moisture in the air remains constant ($\omega_1 = \omega_2$) as it flows through the heating section since the process involves no humidification or dehumidification. The inlet state of the air is completely specified, and the total pressure is 200 kPa. The properties of the air at the inlet and exit states are determined to be

$$P_{v1} = \phi_1 P_{g1} = \phi_1 P_{\text{sat @ 15°C}} = (1.0)(1.7057\text{ kPa}) = 1.7057\text{ kPa}$$

$$h_{g1} = h_{g\text{ @ 15°C}} = 2528.3\text{ kJ/kg}$$

$$P_{a1} = P_1 - P_{v1} = 200 - 1.7057 = 198.29\text{ kPa}$$

$$\boldsymbol{v}_1 = \frac{R_a T_1}{P_{a1}} = \frac{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(288\text{ K})}{198.29\text{ kPa}} = 0.4168\text{ m}^3/\text{kg dry air}$$



$$\omega_1 = \frac{0.622\,P_{v1}}{P_1 - P_{v1}} = \frac{0.622(1.7057\text{ kPa})}{(200 - 1.7057)\text{ kPa}} = 0.005350\text{ kg H}_2\text{O/kg dry air}$$

$$h_1 = c_p T_1 + \omega_1 h_{g1} = (1.005\text{ kJ/kg}\cdot°\text{C})(15°\text{C}) + (0.005350)(2528.3\text{ kJ/kg}) = 28.60\text{ kJ/kg dry air}$$

$$P_{v2} = P_{v1} = 1.7057\text{ kPa}$$

$$P_{g2} = P_{\text{sat @ 30°C}} = 4.2469\text{ kPa}$$

$$\phi_2 = \frac{P_{v2}}{P_{g2}} = \frac{1.7057\text{ kPa}}{4.2469\text{ kPa}} = 0.402 = \mathbf{40.2\%}$$

$$h_{g2} = h_{g\text{ @ 30°C}} = 2555.6\text{ kJ/kg}$$

$$\omega_2 = \omega_1$$

$$h_2 = c_p T_2 + \omega_2 h_{g2} = (1.005\text{ kJ/kg}\cdot°\text{C})(30°\text{C}) + (0.005350)(2555.6\text{ kJ/kg}) = 43.82\text{ kJ/kg dry air}$$

Then,

$$\dot{\boldsymbol{V}}_1 = V_1 A_1 = V_1 \frac{\pi D^2}{4} = (20\text{ m/s})\left(\frac{\pi (0.04\text{ m})^2}{4}\right) = 0.02513\text{ m}^3/\text{s}$$

$$\dot{m}_a = \frac{\dot{\boldsymbol{V}}_1}{\boldsymbol{v}_1} = \frac{0.02513\text{ m}^3/\text{s}}{0.4168\text{ m}^3/\text{kg dry air}} = 0.06029\text{ kg/s}$$

From the energy balance on air in the heating section,

$$\dot{Q}_{\text{in}} = \dot{m}_a (h_2 - h_1) = (0.06029\text{ kg/s})(43.82 - 28.60)\text{kJ/kg} = \mathbf{0.918\text{ kW}}$$