44 Systems and Components

44.1 During winter operation an outside air handler pre-heats and humidifies $20°F$ air with 50% relative humidity to $65°F$ and 40% relative humidity. The humidification process consumes $^1/_2 gpm$ of water. What volume flow rate is required by the fan?

A. $11,000 cfm$

B. $12,000 cfm$

C. $13,000 cfm$

D. $14,000 cfm$

Both states are fully defined, however there is no information about the sensible or total load. Therefore focus on the humidification process. Use the Psychrometric Chart to obtain the humidity ratio for the outside air and the preheated air. Also note the specific volume for the entering air condition.

For State 1:

$$T_1 = 20°F$$

$$\phi_1 = 50\%$$

$$\omega_1 = .00107 \frac{lb_w}{lb_{da}}$$

$$v_1 = 12.16 \frac{ft^3}{lb}$$

For State 2:

$$T_2 = 65°F$$

$$\phi_2 = 40\%$$

$$\omega_2 = .00524 \frac{lb_w}{lb_{da}}$$

Calculate the change in humidity ratio:

$$\Delta\omega = \omega_2 - \omega_1 = .00524 \frac{lb_w}{lb_{da}} - .00107 \frac{lb_w}{lb_{da}} = .00417 \frac{lb_w}{lb_{da}}$$

Convert the mass flow rate of water from gpm to $\frac{lb}{min}$:

$$\dot{m} = \rho \dot{V}$$

$$\dot{m}_w = \left(62.4\frac{lb}{ft^3}\right)\left(\frac{1ft^3}{7.48gal}\right)\left(.5\frac{gal}{min}\right) = 4.17\frac{lb}{min}$$

Apply the definition of the humidity ratio and solve for the mass flow rate of air. Isolate $\dot{m}_a$ and solve:

$$\dot{m}_w = \dot{m}_a\Delta\omega \rightarrow \dot{m}_a = \frac{\dot{m}_w}{\Delta\omega} = \frac{4.17\frac{lb_w}{min}}{.00417\frac{lb_w}{lb_{da}}} = 1000\frac{lb_{da}}{min}$$

Use the specific volume to change the mass flow rate of air to a volume flow rate:

$$\dot{V} = \dot{m}_a v = \left(1000\frac{lb}{min}\right)\left(12.16\frac{ft^3}{lb}\right) = 12,160cfm$$

Answer B