

$$v_1 = 13.8 \frac{ft^3}{lb}$$

$$T_{2,db} = 60^\circ F$$

$$T_{2,wb} = 58^\circ F$$

$$\omega_2 = .0098 \frac{lb_w}{lb_{da}}$$

The mass flow rate of air can be expressed as the volume flow rate divided by the specific volume:

$$\dot{m}_a = \frac{\bar{Q}}{v} = \frac{10,000 \frac{ft^3}{min}}{13.8 \frac{ft^3}{lb_{da}}}$$

Substitute this expression into the first formula for the mass flow rate of air entering the coil, along with the humidity ratios, and solve for the mass flow rate of water removed. Convert units to *gpm* by using the density of water and the **measurement relationship** between gallons and cubic feet. Alternatively, search **Commonly Used Equivalents** to convert directly from *lb* to *gal* in one step using $8.34 \frac{lb_m}{gal}$ for water.

$$\dot{m}_w = \dot{m}_a (\omega_1 - \omega_2) = \left(\frac{10,000 \frac{ft^3}{min}}{13.8 \frac{ft^3}{lb_{da}}} \right) \left(0.0116 \frac{lb_w}{lb_{da}} - 0.0098 \frac{lb_w}{lb_{da}} \right) = 1.3 \frac{lb_w}{min}$$

$$\dot{m}_w = 1.3 \frac{lb}{min} \left(\frac{1 ft^3}{62.4 lb} \right) \left(\frac{7.48 gal}{1 ft^3} \right) = 0.16 gpm$$

Answer C

41.10 What is the specific heat capacity of atmospheric air at $90^\circ F$ dry bulb and $70^\circ F$ wet bulb?

- A. $0.238 \frac{Btu}{lb_m \cdot ^\circ F}$
- B. $0.240 \frac{Btu}{lb_m \cdot ^\circ F}$
- C. $0.242 \frac{Btu}{lb_m \cdot ^\circ F}$
- D. $0.245 \frac{Btu}{lb_m \cdot ^\circ F}$

Typically the specific heat capacity of air at standard temperature and pressure may be taken as the standard value of $c_{p,air} = 0.240 \frac{Btu}{lb_m \cdot ^\circ F}$, as given in the Reference Handbook table **Thermal and Physical Properties of Ideal Gases**. However, there is an embedded assumption that the air is dry air. But in fact, the mixture contains both dry air (nitrogen and oxygen) and water vapor. Using the same table, or by searching **specific heat of water vapor**, note that $c_{p,steam} = 0.445 \frac{Btu}{lb_m \cdot ^\circ F}$. By treating moist air as a mixture of dry air and water vapor, recognize the specific heat capacity will depend on the mass fraction of each substance. Option A should be eliminated because the specific

heat capacity of water vapor is greater than that of dry air, therefore a reduction in the specific heat capacity of the mixture is unrealistic. Option B should remain in play in case the impact of the water vapor turns out to be insignificant.

To find the mass fraction of water vapor, use the **psychrometric chart** to find the humidity ratio for the fully defined state:

$$T_{db} = 90^\circ F$$

$$T_{wb} = 70^\circ F$$

$$\omega = 0.0112 \frac{lb_w}{lb_{da}}$$

Imagine a box of moist air with the humidity ratio as noted. Suppose there is exactly 1 pound of dry air. There must be a corresponding 0.0112 pounds of water vapor present to achieve the humidity ratio. For convenience, assume the box has a total mass of 1.0112 pounds of moist air. Specify the mass fractions water vapor and dry air:

$$x_w = \frac{m_w}{m_w + m_{da}} = \frac{0.0112 lb}{0.0112 lb + 1 lb} = .011 = 1.1\%$$

$$x_{da} = \frac{m_{da}}{m_w + m_{da}} = \frac{1 lb}{0.0112 lb + 1 lb} = .989 = 98.9\%$$

The specific heat capacity of the mixture can be determined with a mixing calculation based on mass fractions and specific heat capacities of dry air and steam. The formula used below is inferred and not provided explicitly in the handbook.

$$c_{p,mixture} = c_{p,air}x_{da} + c_{p,steam}x_w$$

$$c_{p,mixture} = \left(0.240 \frac{Btu}{lb_m \cdot ^\circ F}\right) (0.989) + \left(0.445 \frac{Btu}{lb_m \cdot ^\circ F}\right) (0.011) = 0.242$$

Note that the answer choices are close enough in value to warrant a high level of precision in this case.

Answer C