

**35.31** A 12ft by 15ft room with a 9ft ceiling has a relative humidity of 25% and a dry bulb temperature of 70°F. A humidifier is turned on and run continuously adding 0.04gallons of water per hour to the room. Assuming the additional moisture content has no impact on the dry bulb temperature and the room is sealed, how long will it take to achieve 50% relative humidity?

- A. 0.75 hours
- B. 1 hour
- C. 1.5 hours
- D. 2.75 hours

Use the **Psychrometric Chart** to determine the humidity ratio and specific volume for the initial state:

$$T_1 = 70^\circ F$$

$$\phi_1 = 25\%$$

$$\omega_1 = 0.00388 \frac{lb_w}{lb_{da}}$$

$$v_1 = 13.49 \frac{ft^3}{lb}$$

Also determine the humidity ratio for the final state, after humidification:

$$T_2 = 70^\circ F$$

$$\phi_2 = 50\%$$

$$\omega_2 = 0.00781 \frac{lb_w}{lb_{da}}$$

Calculate the change in the humidity ratio. This is the amount of water that will be added via humidification *per unit mass of dry air*.

$$\Delta\omega = \omega_2 - \omega_1 = 0.00781 \frac{lb_w}{lb_{da}} - 0.00388 \frac{lb_w}{lb_{da}} = 0.00393 \frac{lb_w}{lb_{da}}$$

Calculate the volume of the room:

$$V = (12ft)(15ft)(9ft) = 1620ft^3$$

Calculate the mass of air, including both dry air and water vapor, in the room initially:

$$m_1 = \frac{V}{v_1} = \frac{1620 \text{ ft}^3}{13.49 \frac{\text{ft}^3}{\text{lb}}} = 120.1 \text{ lb}$$

For each pound of dry air in the room initially, there is a corresponding mass of  $0.00388 \frac{\text{lb}_w}{\text{lb}_{da}}$ . To state the same thing a different way, the mass of dry air initially in the room can be calculated as:

$$m_{da,1} = 120.1 \text{ lb} \left( \frac{1 \text{ lb}}{1.00388 \text{ lb}} \right) = 119.6 \text{ lb}_{da}$$

Calculate the mass of water added to the starting mass of dry air, using the change in humidity ratio,  $\Delta\omega$ :

$$m_{w,added} = m_{da} \Delta\omega = (119.6 \text{ lb}_{da}) \left( .00393 \frac{\text{lb}_w}{\text{lb}_{da}} \right) = 0.47 \text{ lb}_w$$

The mass flow rate of water is given. Determine the time required to add the mass of water at a known rate, converting units where necessary:

$$\dot{m} = \frac{m}{t} \rightarrow t = \frac{m}{\dot{m}}$$

$$t = \frac{(.47 \text{ lb})}{\left( .04 \frac{\text{gal}}{\text{hr}} \right) \left( \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right) \left( 62.4 \frac{\text{lb}}{\text{ft}^3} \right)} = 1.41 \text{ hr}$$

To save time, it may be reasonable to assume the entire  $120.1 \text{ lb}$  mass of air is dry air (not strictly true), which would cause the final answer to be overstated by only  $\sim 0.5\%$ , and still allow for selecting the correct choice.

**Answer C**