41.13 Air at $90°F$ dry bulb and $75°F$ wet bulb enters a cooling tower and leaves at $80°F$ saturated. What is the change in moisture content per cubic foot of air?

A. $0.0005 \frac{lb_w}{ft^3}$

B. $0.007 \frac{lb_w}{ft^3}$

C. $0.4 \frac{lb_w}{ft^3}$

D. $5.2 \frac{lb_w}{ft^3}$

Refer to the entering air condition as state 1 and the leaving air condition as state 2. Both states are fully defined. Use the psychrometric chart to find the humidity ratio for both states, then calculate the difference. Also find the specific volume for state 1.

$$T_{1,db} = 90°F$$

$$T_{1,wb} = 75°F$$

$$\omega_1 = 0.0153 \frac{lb_w}{lb_{da}}$$

$$v_1 = 14.2 \frac{ft^3}{lb_{da}}$$

$$T_{2,db} = 80°F$$

$$T_{2,wb} = 80°F$$

$$\omega_2 = 0.0223 \frac{lb_w}{lb_{da}}$$

$$\Delta\omega = \omega_2 - \omega_1 = 0.0223 \frac{lb_w}{lb_{da}} - 0.0153 \frac{lb_w}{lb_{da}} = .007 \frac{lb_w}{lb_{da}}$$

In order to express the humidity per unit volume rather than per unit mass of dry air, divide $\Delta\omega$ by the specific volume of the entering air, v_1. The reference handbook calls this the absolute humidity or water vapor density, d_v.

$$d_v = \frac{.007 \frac{lb_w}{lb_{da}}}{14.2 \frac{ft^3}{lb_{da}}} = 0.0005 \frac{lb_w}{ft^3}$$

Answer A

41.14 An auditorium has a sensible heat load of $300,000\frac{Btu}{hr}$ and a moisture load of $100\frac{lb}{hr}$. Air is supplied at $62°F$ and 50% relative humidity. The space is not to exceed a temperature of $74°F$ or a relative humidity of 60%. What are the return air conditions?

A. $71°F$, 60% RH

B. $72°F$, 43% RH

C. $74°F$, 38% RH

D. $74°F$, 60% RH

Initially it is not clear whether the CFM will be driven by the sensible cooling demand or the latent cooling demand. One approach is to guess, solve, and then check to make sure the other parameter is satisfied. In this case, assume the sensible heat load drives the required CFM, then check to make sure the room relative humidity does not exceed 60%.

Start with the sensible cooling rule of thumb. Refer to Heat Gain Calculations in the Reference Handbook:

$$q_s = 1.08cfm\Delta T \rightarrow cfm = \frac{q_s}{1.08\Delta T}$$

$$cfm = \frac{300,000}{1.08\,(74-62)} = 23,148cfm$$

Look up latent heat gain and use the approximate heat content of water vapor to convert the latent heat load into $\frac{Btu}{hr}$:

$$q_L = \left(100\frac{lb}{hr}\right)\left(1076\frac{Btu}{lb}\right) = 107,600\frac{Btu}{hr}$$

Apply the latent heat gain rule of thumb and solve for the humidity ratio of the return air. Use the psychrometric chart to look up the humidity ratio for the supply condition:

$$T_{s,db} = 62°F$$

$$\phi_s = 50\%$$

$$\omega_s = 0.0059\frac{lb_w}{lb_{da}}$$

$$q_L = 4840cfm\Delta\omega = 4840cfm\,(\omega_r - \omega_s)$$

$$\omega_r = \frac{q_L}{4840cfm} + \omega_s = \frac{107,600}{4840\,(23,148)} + 0.0059 = 0.0068\frac{lb_w}{lb_{da}}$$

$$T_{r,db} = 74°F$$