**41.4 An air handling system to be used at $6500 ft$ above sea level is designed for outside air at $65°F$ and 60% relative humidity. What is the density of the outside air?**

A. $0.058\frac{lb_m}{ft^3}$

B. $0.062\frac{lb_m}{ft^3}$

C. $0.074\frac{lb_m}{ft^3}$

D. $0.076\frac{lb_m}{ft^3}$

This problem requires performing an elevation correction. Start by finding the density of air for sea level conditions using the psychrometric chart. As sea level:

$$T_0 = 65°F$$

$$\phi_0 = 60\%$$

$$v_0 = 13.4\frac{ft^3}{lb}$$

The air density at sea level is the inverse of the specific volume:

$$\rho_0 = \frac{1}{v_0} = \frac{1}{13.4\frac{ft^3}{lb}} = .0746\frac{lb}{ft^3}$$

To set up the elevation correction equation properly, recall the relationship between pressure and density by considering the ideal gas law:

$$PV = nRT \to Pv = mRT \to P = \rho RT \to P \sim p$$

Since $R$ is a constant and $T$ is not changing, it is clear that the pressure and density are proportional i.e. they change linearly together, as below:

$$\frac{\rho_{6500}}{\rho_0} = \frac{P_{6500}}{P_0} = \left[1 - (elevation)\left(6.875 \times 10^{-6}\right)\right]^{5.256}$$

$$\left[1 - (6500)\left(6.875 \times 10^{-6}\right)\right]^{5.256} = 0.786$$

Solve for the density at $6500 ft$ using the sea level density $\rho_0$:

$$\frac{\rho_{6500}}{\rho_0} = 0.786$$

$$\rho_{6500} = \left(0.0746\frac{lb}{ft^3}\right)(0.786) = 0.0587\frac{ft^3}{lb}$$

Alternatively, use the table Temperature and Altitude Corrections for Air to obtain the densifty factor at 6,500ft elevation, and multiply by the sea level density per the final step shown.

**Answer A**

**41.5 A cooling tower cools $150gpm$ of condenser water maintaining a $15°F$ delta T. On a design day, air enters the cooling tower at $90°F$ dry bulb and $75°F$ wet bulb and leaves at $105°F$ dry bulb and 80% relative humidity. What volume flow rate of air through the cooling towers is required?**

A. $8100cfm$

B. $12,500cfm$

C. $69,400cfm$

D. $119,700cfm$

The quantity of heat removed from the air is added to the condenser water. Therefore:

$$Q_a = Q_w$$

The sensible heating of the condenser water can be determined using the rule of thumb, where the flow rate and differential temperature are known:

$$Q_w = 500gpm\Delta T = 500\,(150)\,(15) = 1,125,000\frac{Btu}{hr}$$

The heat removed from air in a cooling tower is driven by a substantial amount of evaporation; therefore, use the rule of thumb for *total* cooling of air (including both sensible and latent) should be used:

$$Q_a = 4.5cfm\Delta h$$

where the volume flow rate of air is unknown. To specify the change in enthalpy, use the psychrometric chart to look up the enthalpy values for entering and leaving conditions, both of which are fully defined. Use of the high temperature psychrometric chart is required for State 2.

| State 1: Entering Air | State 2: Leaving Air |
|---|---|
| $T_{1,db} = 90°F$ | $T_{2,db} = 105°F$ |
| $T_{1,wb} = 75°F$ | $T_{2,wb}$ |
| $\phi_1$ | $\phi_2 = 80\%$ |
| $h_1 = 38.4\frac{Btu}{lb}$ | $h_2 = 69.4\frac{Btu}{lb}$ |

Calculate the change in enthalpy:

$$\Delta h = h_2 - h_1 = 69.4\frac{Btu}{lb} - 38.4\frac{Btu}{lb} = 31\frac{Btu}{lb}$$

Use the fact that $Q_a = Q_w$ to solve for the unknown volume flow rate. Note that by using the rule of thumb selected, the units will automatically come out in $cfm$ provided the enthalpy is in $\frac{Btu}{lb}$ and the heat transfer is in $\frac{Btu}{hr}$.

$$cfm = \frac{1,125,000}{(4.5)\,(31)} = 8065cfm$$

**Answer A**