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
$T_{1,db} = 90°F$	$T_{2,db} = 105°F$
$T_{1,wb} = 75°F$	$T_{2,wb}$
ϕ_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

41.6 Air enters an evaporative cooler at $85°F$ and 30% relative humidity and exits at $75°F$. What is the saturation efficiency?

A. 37%

B. 47%

C. 53%

D. 63%

The saturation efficiency of an evaporative cooler is defined by the formula:

$$\varepsilon = 100\frac{(T_1 - T_2)}{(T_1 - T_s^{'})}$$

where T_1 is the entering air dry bulb temperature, T_2 is the leaving air dry bulb temperature, and $T_s^{'}$ is the wet bulb temperature of the entering air. The entering wet bulb temperature is the minimum possible leaving air temperature achievable, such that for a 100% efficient process, $T_2 = T_s^{'}$.

Since both the entering and leaving dry bulb temperatures are known, the only additional information to be determined is the entering wet bulb, which can be pulled from the psychrometric chart since the entering state is fully defined:

$$T_{1,db} = 85°F$$

$$\phi_1 = 30\%$$

$$T_{1,wb} = 63.6°F$$

Calculate the saturation efficiency:

$$\varepsilon = 100\frac{(T_1 - T_2)}{(T_1 - T_s^{'})} = 100\frac{(85°F - 75°F)}{(85°F - 63.6°F)} = 47\%$$

Answer B