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

41.7 During winter operation, $5000 cfm$ of outside air at $40°F$ and 60% relative humidity is pre-heated with a $50KW$ electric coil, then humidified to 50% relative humidity. What is the total increase in heat?

A. $46,000 \frac{Btu}{hr}$

B. $124,000 \frac{Btu}{hr}$

C. $170,000 \frac{Btu}{hr}$

D. $300,000 \frac{Btu}{hr}$

Use the rule of thumb for total heat added to air, including both sensible and latent:

$$Q_t = 4.5 cfm \Delta h$$

The entering condition, state 1, is fully defined for the outside air. Use the psychrometric chart to look up the enthalpy:

$$T_{1,db} = 40°F$$

$$\phi_1 = 60\%$$

$$h_1 = 13 \frac{Btu}{lb}$$

Define state 2 as the condition after the sensible heating but before the humidification. Define state 3 as the final condition after the humidification. Only the relative humidity is known for state 3. Therefore, it is necessary to work with state 2 to gather more information that will be relevant for state 3.

The process from $1 \rightarrow 2$ is sensible heating of a known quantity. Use the sensible rule of thumb to determine the dry bulb temperature at state 2. The quantity of heating is the capacity of the electric coil. Convert units from KW to $\frac{Btu}{hr}$.

$$Q_s = 1.08 cfm \Delta T$$

$$\Delta T = \frac{Q_s}{1.08 cfm} = \frac{(50KW)\left(3412 \frac{Btu}{hr \cdot KW}\right)}{(1.08)(5000)} = 31.6°F$$

$$\Delta T = T_2 - T_1 = 31.6°F$$

$$T_2 = T_1 + 31.6°F = 40F + 31.6°F = 71.6°F$$

The process $2 \rightarrow 3$ is latent heating which is vertically up on the psychrometric chart. Latent heating does not change the dry bulb temperature. Therefore:

$$T_3 = T_2 = 71.6°F$$