37.14 Water enters a $100ton$ cooling tower at $130°F$ and leaves at $105°F$. Air enters at $88°F$ and 60% RH and leaves at $104°F$ and 80% RH. What quantity of make up water is required? Assume no losses.

A. $0.25GPM$

B. $0.5GPM$

C. $1GPM$

D. $2GPM$

The cooling tower entering and leaving water temperatures are extra information and not needed to solve the problem. The rate of heat transfer *to* the air is equivalent to the rate of heat transfer *from* the condenser water.

$$\dot{Q}_{cw} = \dot{Q}_{air} = 100tons\left(12,000\frac{Btu}{hr \cdot ton}\right) = 1,200,000\frac{Btu}{hr}$$

Set this quantity equal to a $m\Delta h$ expression, where entering air is State 1 and the leaving air is State 2. Both states are fully defined and enthalpy values as well as humidity ratios may be obtained using the Psychrometric Chart and High Temperature Psychrometric Chart, where required.

$$\dot{Q}_{air} = \dot{m}_{air}\Delta h$$

For the entering air, State 1:

$$T_1 = 88°F$$

$$\phi_1 = 60\%$$

$$h_1 = 40.03\frac{Btu}{lb}$$

$$\omega_1 = .01719\frac{lb_w}{lb_{da}}$$

For the leaving air, State 2:

$$T_2 = 104°F$$

$$\phi_2 = 80\%$$

$$h_2 = 67.76\frac{Btu}{lb}$$

$$\omega_2 = .03866\frac{lb_w}{lb_{da}}$$

Solve for the mass flow rate of air. Convert units to $\frac{lb}{min}$:

$$\dot{Q}_{air} = \dot{m}_{air}\Delta h \rightarrow \dot{m}_{air} = \frac{\dot{Q}_{air}}{h_2 - h_1} = \frac{1,200,000\frac{Btu}{hr}}{\left(67.76\frac{Btu}{lb} - 40.03\frac{Btu}{lb}\right)} = 43,274\frac{lb}{hr}$$

$$\dot{m}_{air} = 43,274\frac{lb}{hr}\left(\frac{1hr}{60min}\right) = 721.2\frac{lb}{min}$$

Find the mass flow rate of water being added to the air stream and convert to *gpm*. Note, the formula used is derived from the definition of the humidity ratio and is best memorized rather than looked up or derived:

$$\dot{m}_w = \dot{m}_a\left(\omega_2 - \omega_1\right)$$

$$\dot{m}_w = \left(721.2\frac{lb}{min}\right)\left(.03866\frac{lb_w}{lb_{da}} - .01719\frac{lb_w}{lb_{da}}\right) = 15.5\frac{lb}{min}$$

$$\dot{m}_w = 15.5\frac{lb}{min}\left(\frac{1ft^3}{62.4lb}\right)\left(\frac{7.48gal}{1ft^3}\right) = 1.86gpm$$

Answer D