

44.11 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:

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

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:

$$T_1 = 88^\circ F$$

$$\phi_1 = 60\%$$

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

$$\omega_1 = .01719 \frac{\text{lb}_w}{\text{lb}_{da}}$$

For the leaving air, State 2:

$$T_2 = 104^\circ F$$

$$\phi_2 = 80\%$$

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

$$\omega_2 = .03866 \frac{\text{lb}_w}{\text{lb}_{da}}$$

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

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

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

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:

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

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

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

Answer D

44.12 R-410a is used in a chiller with a suction pressure of 60psia and a discharge pressure of 185psia. The refrigeration cycle operates with 20°F of sub cooling and 20°F of superheating. The load on the chiller is 200tons. What is the mass flow rate of refrigerant?

- A. 420 $\frac{lb}{min}$
- B. 440 $\frac{lb}{min}$
- C. 460 $\frac{lb}{min}$
- D. 480 $\frac{lb}{min}$

Look up **Pressure Versus Enthalpy Curves for Refrigerant 410A** in the Reference Handbook and draw the refrigeration cycle directly on the screen. If drawing on the screen is unworkable, sketch on scrap paper and mark key values obtained from the chart on the axes. Note the vertical axis is nonlinear so take special care to identify the low and high pressure conditions for the evaporator and condenser.

The load on the chiller is the refrigeration effect, \dot{Q}_{in} . Express the refrigeration effect as the mass flow rate times the change in enthalpy across the evaporator, typically represented as $h_1 - h_4$.

$$\dot{Q}_{in} = \dot{m} (h_1 - h_4)$$

State 1, leaving the evaporator and entering the condenser, must be selected to the right of the saturation curve in the superheated region to account for 20°F of superheat.