43.4 During winter operation a $2000 cfm$ outside air handling unit uses steam to humidify an office. The design outside conditions are $10°F$, 50% RH. The inside conditions are maintained at $74°F$, 50% RH. How much water is required to humidify for a 24 hour period during design conditions? Neglect internal latent load.

A. $10 gal$

B. $110 gal$

C. $210 gal$

D. $240 gal$

Both the inside and outside conditions are fully defined; however, the humidity ratio at the low temperature (outside) condition cannot be looked up in the Reference Handbook. For study purposes only, use the MERM low temperature psychrometric chart, an online psychrometric calculator, or take the value as a given. Alternatively, take the humidity ratio outside as zero because air at 10°F can hold very little moisture.

Let the entering air condition be state 1 and the room condition be state 2. Use the psychrometric chart where possible. Also obtain the specific volume for state 1, or estimate by extrapolating.

$$T_1 = 10°F$$

$$\phi_1 = 50\%$$

$$\omega_1 = .00065 \frac{lb_w}{lb_{da}} \approx 0 \frac{lb_w}{lb_{da}}$$

$$v_1 = 11.85 \frac{ft^3}{lb}$$

$$T_2 = 74°F$$

$$\phi_2 = 50\%$$

$$\omega_2 = .00893 \frac{lb_w}{lb_{da}}$$

Find the mass flow rate of water vapor being added to the air by using the formula below. This formula is used frequently and should be memorized. It is derived from the definition of the humidity ratio and may not be presented explicitly in the Reference Handbook.

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

where the mass flow rate, $\dot{m}_a$, can be expressed as volume flow rate divided by specific volume:

$$\dot{m} = \frac{\dot{V}}{v}$$

Substitute and solve:

$$\dot{m}_w = \frac{\dot{V}}{v}(\omega_2 - \omega_1)$$

$$\dot{m}_w = \frac{\left(2000\frac{ft^3}{min}\right)}{\left(11.85\frac{ft^3}{lb}\right)}\left(.00893\frac{lb_w}{lb_{da}} - .00065\frac{lb_w}{lb_{da}}\right) = 1.4\frac{lb}{min}$$

Multiply by time and divide by density to find the volume of water added in 24 hours. Note if the humidity ratio of state 1 is taken as zero, the result will be overstated by 7%, still leading to the correct answer choice.

$$1.4\frac{lb}{min}\left(60\frac{min}{hr}\right)(24hr)\left(\frac{1ft^3}{62.4lb}\right)\left(\frac{7.48gal}{ft^3}\right) = 242\,gal$$

Answer D

43.5 A warehouse located in a damp climate uses two-pipe heating fan coil units to maintain a maximum relative humidity of 60%. With the fan coil units disabled and all heating control valves closed, the room reaches $62°F$ and 80% RH. There are (12) $\times$ $200cfm$ fan coil units. What is the required heating capacity per unit?

A. $1800\frac{Btu}{hr}$

B. $2300\frac{Btu}{hr}$

C. $22,000\frac{Btu}{hr}$

D. $28,000\frac{Btu}{hr}$

The fan coil units provide heating only; therefore, they cannot remove any moisture from the air, as that would require a cooling process to drive dehumidification. To maintain a maximum relative humidity, the air must be heated. This may initially seem counter-intuitive, but recall that warmer air has a greater *capacity* for holding moisture. Sufficient heating (without any change to the humidity ratio) will drive the relative humidity down.

Drawing this on the psychrometric chart, the process line is horizontal to the right for purely sensible heating. State 1 is fully defined. Obtain the dew point temperature (alternatively the humidity ratio may also be used, as both parameters will keep the process line horizontal when held constant).

$$T_{db,1} = 62°F$$

$$\phi_1 = 80\%$$