$$h_f = 180.18\frac{Btu}{lb}$$

$$h_{fg} = 970.07\frac{Btu}{lb}$$

$$h_{2,ideal} = h_f + \chi_2 h_{fg} = 180.18\frac{Btu}{lb} + 0.92\left(970.07\frac{Btu}{lb}\right) = 1072.7\frac{Btu}{lb}$$

Apply the turbine efficiency to determine the actual enthalpy at State 2, $h_2^{'}$. Recognize the actual change in enthalpy, $\Delta h_{actual} = h_1 - h_2^{'}$, is less than the ideal change in enthalpy, $\Delta h_{ideal} = h_1 - h_2$, as dictated by the turbine efficiency. Rearrange for $h_2^{'}$, substitute, and solve.

$$\eta = \frac{\Delta h_{actual}}{\Delta h_{ideal}} = \frac{h_1 - h_2^{'}}{h_1 - h_2}$$

$$h_2^{'} = h_1 - \eta\left(h_1 - h_2\right)$$

$$h_2^{'} = 1362.9\frac{Btu}{lb} - 0.85\left(1362.9\frac{Btu}{lb} - 1072.7\frac{Btu}{lb}\right) = 1116\frac{Btu}{lb}$$

Answer A

46.77 A room with a volume of $50,000ft^3$is maintained at $72°F$ and 40% relative humidity. The space requires five air changes per hour of ventilation. On a winter design day, the outdoor temperature is $0°F$. What is the required humidification capacity to satisfy this application?

A. $2\frac{lb}{hr}$

B. $60\frac{lb}{hr}$

C. $140\frac{lb}{hr}$

D. $1300\frac{lb}{hr}$

Use the air changes per hour and the volume of the room to calculate the volume flow rate being supplied and exhausted from the space.

$$Q = \left(5\frac{air\ changes}{hr}\right)\left(50,000\frac{ft^3}{air\ change}\right)\left(\frac{1hr}{60min}\right) = 4167cfm$$

The room condition is fully defined. Use the Psychrometric Chart to obtain the humidity ratio for the indoor conditions.

$$T_r = 72°F$$

$$\phi_r = 40\%$$

$$\omega_r = 0.00668 \frac{lb_w}{lb_{da}}$$

To find the required humidification, it is necessary to quantify the change in humidity ratio, which requires specifying the humidity ratio for the outdoor conditions, ω_{OA}. However, the Reference Handbook does not furnish a low temperature psychrometric chart, and the problem statement provides only the temperature without a second data point to better define the state. Fortunately, the Reference Handbook does provide a table underneath the Psychrometric Charts called Thermodynamic Properties of Moist Air which provides the humidity ratio for fully saturated $0°F$ air. From the perspective of sizing the humidification system, saturated outside air would be a best-case scenario.

$$\omega_{OA,sat} = 0.000788 \frac{lb_w}{lb_{da}}$$

Altenratively, the worst-case scenario would be completely dry outside air.

$$\omega_{OA,dry} = 0 \frac{lb_w}{lb_{da}}$$

By establishing a bounded range for the outside moisture levels, recognize the limited capacity of cold air to hold moisture, and conclude that the change in humidity is largely driven by the *internal* requirements and little contribution is being made from the outside regardless of relative humidity. Calculate the change in the humidity ratio using both values to observe the negligible difference in the results.

$$\Delta\omega_{min} = \omega_r - \omega_{OA,sat} = 0.00668 \frac{lb_w}{lb_{da}} - 0.000788 \frac{lb_w}{lb_{da}} = 0.0059 \frac{lb_w}{lb_{da}}$$

$$\Delta\omega_{max} = \omega_r - \omega_{OA,dry} = 0.00668 \frac{lb_w}{lb_{da}} - 0 \frac{lb_w}{lb_{da}} = 0.0067 \frac{lb_w}{lb_{da}}$$

Calculate the average value, $\Delta\omega_{avg}$, and set the expectation of up to ~6% error in the final answer, which should be sufficient since the answer choices are generously spaced.

$$\Delta\omega_{avg} = \frac{\Delta\omega_{min} + \Delta\omega_{max}}{2} = \frac{0.0059 \frac{lb_w}{lb_{da}} + 0.0067 \frac{lb_w}{lb_{da}}}{2} = 0.0063 \frac{lb_w}{lb_{da}}$$

Using the equation under Moist-Air Cooling and Dehumidification, calculate the mass flow rate of water that must be added to the air to achieve the desired internal moisture levels as a function of the mass flow rate of entering air and the change in humidity ratio. When finding the mass flow rate of entering outside air, use the specific volume from the table Thermodynamic Properties of Moist Air, recognizing that the variance between dry and saturated conditions is minimal since air's capacity for holding moisture is negligible at low temperatures. Suggest taking a rough average of the table values for convenience.

$$\dot{m}_w = \dot{m}_a \Delta\omega_{avg}$$