44.23 A cooling coil with a sensible capacity of $10tons$ is designed for a $20°F$ delta T. The air handler is installed in a facility at $5000ft$ elevation and must produce a total static pressure of $2.5in\,wg$. Assuming the fan is 92% efficient, what should be the nominal size of the fan motor?

A. $1^1/_2 hp$

B. $2hp$

C. $2^1/_2 hp$

D. $3hp$

Convert the sensible capacity to units of $\frac{Btu}{hr}$:

$$\dot{Q}_s = (10tons)\left(12,000\frac{Btu}{hr \cdot ton}\right) = 120,000\frac{Btu}{hr}$$

The sensible heating and cooling rule of thumb is not valid due to the elevation; however, the section Heat Gain Calculations Using Standard Air Values offers a slight adaptation for air at 5,000 ft. Update the constant in the rule of thumb and proceed with calculating the cfm. Note, the section for Elevation Correction may be useful for other nonstandard elevations.

$$\dot{Q}_s = 0.92cfm\Delta T$$

$$cfm = \frac{\dot{Q}_s}{(.92)(\Delta T)} = \frac{120,000}{(.92)(20)} = 6522cfm$$

Look up Efficiency of Fan in the Reference Handbook and use the formula right above the search result to calculate the air horsepower needed to provide the required volume flow rate against the pressure drop given. Units need not be shown provided the volume flow rate is in cfm and the pressure drop is in $in\,wg$. In a separate step, consider the efficiency to determine the brake horsepower.

$$AHP = \frac{Q_{[cfm]}\Delta P_{[in\,wg]}}{6356}$$

$$AHP = \frac{(6522)(2.5)}{6356} = 2.57hp$$

$$\eta_{fan} = \frac{AHP}{BHP} \rightarrow BHP = \frac{AHP}{\eta_{fan}}$$

$$BHP = \frac{2.57hp}{.92} = 2.79hp$$

Motor sizes are always rated in BHP. Round up to the nearest nominal motor size. For a list of standard motor sizes and efficiencies, look up Average Efficiencies Representing Typical Electric Motors in the Reference Handbook. $3HP$ is included in the list.

Answer D

44.24 What is the size of a refrigeration system required to freeze $100lbs$ of raspberries initially at $65°F$ to $15°F$ in $3hrs$?

A. $1,300\frac{Btu}{hr}$

B. $4,000\frac{Btu}{hr}$

C. $5,500\frac{Btu}{hr}$

D. $16,500\frac{Btu}{hr}$

Look up Refrigeration Properties of Foods and find raspberries. Obtain the freezing point temperature, the specific heat capacity above and below freezing, and the latent heat of fusion from the table. Determine the total heat to be removed from the fruit by calculating the sensible cooling above and below freezing and the latent heat removed (during phase change) at the freezing point.

Above the freezing point:

$$Q_{s,above} = mc_{p,above}\Delta T$$

$$Q_{s,above} = (100lb)\left(.95\frac{Btu}{lb \cdot °F}\right)(65°F - 30.9°F) = 3,240Btu$$

At the freezing point:

$$Q_{L,@FP} = mh_{fusion}$$

$$Q_{L,@FP} = (100lb)\left(124\frac{Btu}{lb}\right) = 12,400Btu$$

Below the freezing point:

$$Q_{s,below} = mc_{p,below}\Delta T$$

$$Q_{s,below} = (100lb)\left(.46\frac{Btu}{lb \cdot °F}\right)(30.9°F - 15°F) = 731Btu$$

Find the total heat removed. Then divide by the time in which that energy is to be removed to determine the capacity of the refrigeration system.

$$Q_{total} = 3,240Btu + 12,400Btu + 731Btu = 16,371Btu$$

$$\dot{Q} = \frac{Q}{t} = \frac{16,371Btu}{3hr} = 5,457\frac{Btu}{hr}$$

Answer C