

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:

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

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

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:

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

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

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

44.25 The top of the waterline of an open cooling tower basin is located $13ft$ above the centerline of the associated $50gpm$ condenser water pump. The entering condenser water for the tower is $92^\circ F$. The outdoor conditions are $68^\circ F$ and 60% relative humidity. The cooling tower effectiveness is 70% . The suction piping between the basin and the condenser pump is comprised of an equivalent length of $25ft$ of $2^{1/2}in$ standard weight steel pipe. What is the net positive suction head available to the condenser water pump in feet of water?

- A. $27ft$
- B. $36ft$
- C. $45ft$
- D. $49ft$

Look up **Net Positive Suction Head** in the Reference Handbook and use the formula for $NPSH_A$:

$$NPSH_A = h_p + h_z - h_{vpa} - h_f$$

where h_p is atmospheric pressure, h_z is the height of the column of water above the suction inlet (negative if the height of the reservoir is below the pump centerline), h_{vpa} is the vapor pressure which is a function of temperature, and h_f is the friction losses associated with the suction side piping path. Consider each term one at a time.

Atmospheric pressure is readily known to be $14.7psia$. For consistency, convert units to ft of head by applying by the rule of thumb conversion factor for water $2.31ft = 1psi$.

$$h_p = 14.7psi \left(\frac{2.31ft}{psi} \right) = 33.96ft$$

The height of the water column on the suction side is given:

$$h_z = 13ft$$

The vapor pressure of water is a function of temperature. The warmer the water, the higher the vapor pressure because more water molecules are likely to undergo phase change and become vapor. The water on the suction side of the condenser water pump is leaving the cooling tower, and the temperature is unknown. However, the entering water temperature is known, the wet bulb temperature can be determined using the outside conditions and the **Psychrometric Chart**, and the cooling tower effectiveness is known. Find the leaving water temperature.

$$T_{OA,db} = 68^\circ F$$

$$\phi_{OA} = 60\%$$

$$T_{OA,wb} = 59.2^\circ F$$