

**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.

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

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

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

The wet bulb temperature is the minimum possible leaving water temperature that could be achieved if the cooling tower effectiveness was 100%. Since the effectiveness is only 70%, the leaving water temperature will be slightly greater.

$$\varepsilon = \frac{EWT - LWT}{EWT - T_{wb}}$$

$$.7 = \frac{92^\circ F - LWT}{92^\circ F - 59.2^\circ F}$$

$$LWT = 69^\circ F$$

Look up the steam table, **Properties of Saturated Water** by Temperature, and obtain the saturation pressure for  $69^\circ F$  water. Convert units to *ft* of water.

$$P_{sat@69^\circ F} = .35psi$$

$$h_{vpa} = (.35psi) \left( \frac{2.31ft}{psi} \right) = .81ft$$

For the friction loss, look up **Steel Pipe Friction Tables** and use the diameter and flow rate given to find the head loss per unit length. Apply the equivalent length given to solve for the total friction loss.

$$D = 2.5in$$

$$Q = 50gpm$$

$$\Delta h_{d,loss} = 3.6 \frac{ft}{100ft}$$

$$h_f = \left( 3.6 \frac{ft}{100ft} \right) (25ft) = .9ft$$

Calculate the net positive suction head available:

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

$$NPSH_A = 33.96ft + 13ft - .81ft - .9ft = 45.25ft$$

**Answer C**