46.76 Superheated steam at $400psia$ and $700°F$ is expanded in a 85% efficient turbine to atmospheric pressure. What is the enthalpy of the saturated mixture exiting the turbine?

A. $1120\frac{Btu}{lb}$

B. $1130\frac{Btu}{lb}$

C. $1140\frac{Btu}{lb}$

D. $1150\frac{Btu}{lb}$

Sketch the turbine. Consider the entering superheated steam as State 1 and the exiting saturated mixture as State 2. Use the Properties of Superheated Steam table to determine the enthalpy and entropy at State 1, which is fully defined since the temperature and pressure are both known.

$$P_1 = 400psia$$

$$T_1 = 700°F$$

$$h_1 = 1362.9\frac{Btu}{lb}$$

$$s_1 = 1.641\frac{Btu}{lb°R}$$

Initially assume isentropic expansion to find the ideal exit quality at State 2.

$$s_2 = s_1 = 1.641\frac{Btu}{lb°R}$$

Use the Properties of Saturated Water and Steam (Pressure) table to look up s_f and s_{fg} at $P_2 = 1atm = 14.7psia$.

$$s_f = 0.3122\frac{Btu}{lb°R}$$

$$s_{fg} = 1.4443\frac{Btu}{lb°R}$$

Rearrange the formula relating entropy and quality from Properties for Two-Phase (Vapor-Liquid) Systems.

$$s_2 = s_f + \chi_2 s_{fg} \rightarrow \chi_2 = \frac{s_2 - s_f}{s_{fg}}$$

$$\chi_2 = \frac{1.641\frac{Btu}{lb°R} - 0.3122\frac{Btu}{lb°R}}{1.4443\frac{Btu}{lb°R}} = 0.92$$

Use the ideal quality at State 2 to determine the ideal enthalpy at State 2. Return to the Properties of Saturated Water and Steam (Pressure) table to obtain the enthalpies h_f and h_{fg} at $P_2 = 14.7psia$.

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

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

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

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 $50,000 ft^3$ 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.

$$T_r = 72°F$$