34.2 A 90% efficient turbine expands superheated steam entering at $500°F$ and $200psia$ to atmospheric pressure. What is the enthalpy of the leaving steam?

A. $970\frac{Btu}{lb}$

B. $1061\frac{Btu}{lb}$

C. $1082\frac{Btu}{lb}$

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

Consider the superheated steam entering the turbine as State 1 and the leaving steam as State 2. Use the Superheated Steam table to look up the enthalpy and entropy for State 1.

$$T_1 = 500°F$$

$$P_1 = 200psia$$

$$h_1 = 1269\frac{Btu}{lb}$$

$$s_1 = 1.624\frac{Btu}{lb \cdot R}$$

Determine the *ideal* enthalpy at State 2 if the turbine was isentropic i.e. 100% efficient. Use the Saturated Water and Steam table to look up the entropy and enthalpy values. Calculate the quality based on the entropy.

$$s_2 = s_1 = 1.624\frac{Btu}{lb \cdot R}$$

$$P_2 = 14.7psia$$

$$s_f = 0.3122\frac{Btu}{lb \cdot R}$$

$$s_{fg} = 1.4443\frac{Btu}{lb \cdot R}$$

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

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

$$\chi_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{1.624\frac{Btu}{lb \cdot R} - 0.3122\frac{Btu}{lb \cdot R}}{1.4443\frac{Btu}{lb \cdot R}} = 0.908$$

$$h_2 = h_f + \chi_2 h_{fg} = 180.18\frac{Btu}{lb} + (0.908)\left(970.07\frac{Btu}{lb}\right) = 1061.26\frac{Btu}{lb}$$

The *actual* enthalpy at State 2, $h_2^{'}$, will differ from the ideal enthalpy according to the efficiency. Solve for $h_2^{'}$.

$$\eta = \frac{h_1 - h_2}{h_1 - h_2^{'}}$$

$$h_2^{'} = h_1 - \eta\left(h_1 - h_2\right) = 1269\frac{Btu}{lb} - (0.9)\left(1269\frac{Btu}{lb} - 1061.26\frac{Btu}{lb}\right) = 1082\frac{Btu}{lb}$$

Answer C