

31.6 Steam with a quality of 90% expands isentropically from 350psia to 120psia. What is the change in enthalpy?

- A. $40 \frac{Btu}{lb}$
- B. $80 \frac{Btu}{lb}$
- C. $90 \frac{Btu}{lb}$
- D. $120 \frac{Btu}{lb}$

Look up the **Properties of Saturated Water and Steam** in the Reference Handbook organized by pressure and find 350psia. Call this State 1. From the table, $h_f = 409.8 \frac{Btu}{lb}$ and $h_{fg} = 794.62 \frac{Btu}{lb}$. Calculate the enthalpy at State 1:

$$h_1 = h_f + \chi h_{fg} = 409.8 \frac{Btu}{lb} + (0.9) \left(794.62 \frac{Btu}{lb} \right) = 1125 \frac{Btu}{lb}$$

Also gather entropy values from the same line in the table, $s_f = 0.6059 \frac{Btu}{lb_m \cdot ^\circ F}$ and $s_{fg} = 0.8914 \frac{Btu}{lb_m \cdot ^\circ F}$. Calculate the entropy at State 1:

$$s_1 = s_f + \chi s_{fg} = 0.6059 \frac{Btu}{lb_m \cdot ^\circ F} + (0.9) \left(0.8914 \frac{Btu}{lb_m \cdot ^\circ F} \right) = 1.408 \frac{Btu}{lb_m \cdot ^\circ F}$$

Since the expansion from State 1 to State 2 is isentropic:

$$s_2 = s_1 = 1.408 \frac{Btu}{lb_m \cdot ^\circ F}$$

Gather entropy values from the table for State 2, which has a pressure of $P_2 = 120psia$. $s_f = 0.4919 \frac{Btu}{lb_m \cdot ^\circ F}$ and $s_{fg} = 1.0965 \frac{Btu}{lb_m \cdot ^\circ F}$. Find the quality at State 2 (after the isentropic expansion):

$$\chi = \frac{s_2 - s_f}{s_{fg}} = \frac{\left(1.408 \frac{Btu}{lb_m \cdot ^\circ F} \right) - \left(0.4919 \frac{Btu}{lb_m \cdot ^\circ F} \right)}{\left(1.0965 \frac{Btu}{lb_m \cdot ^\circ F} \right)} = 0.835$$

Gather enthalpy values from the table for State 2. $h_f = 312.55 \frac{Btu}{lb}$ and $h_{fg} = 878.2 \frac{Btu}{lb}$. Calculate the enthalpy at State 2:

$$h_2 = h_f + \chi h_{fg} = 312.55 \frac{Btu}{lb} + (0.835) \left(878.2 \frac{Btu}{lb} \right) = 1046 \frac{Btu}{lb}$$

Finally, calculate the change in enthalpy from State 1 to State 2:

$$\Delta h = h_1 - h_2 = 1125 \frac{Btu}{lb} - 1046 \frac{Btu}{lb} = 79 \frac{Btu}{lb}$$

Answer B