

**37.73** Steam enters a turbine at a pressure of  $1000\text{psia}$  and a temperature of  $800^\circ\text{F}$  and exits at a pressure of  $90\text{psia}$  and a temperature of  $400^\circ\text{F}$ . What is the efficiency?

- A. 52%
- B. 67%
- C. 72%
- D. 89%

Consider the entering steam as State 1 and the exit steam as State 2. Both states are fully defined and superheated. Use the properties of **Superheated Steam** tables to look up the enthalpy and entropy for State 1, and the *actual* enthalpy for State 2.

$$P_1 = 1000\text{psia}$$

$$T_1 = 800^\circ\text{F}$$

$$h_1 = 1389 \frac{\text{Btu}}{\text{lb}}$$

$$s_1 = 1.567 \frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{R}}$$

$$P_2 = 90\text{psia}$$

$$T_2 = 400^\circ\text{F}$$

$$h_2' = 1229.3 \frac{\text{Btu}}{\text{lb}}$$

If the expansion process was isentropic, i.e. 100% efficient, the entropy at State 2 would be equal to the entropy at State 1. Use the properties of **Saturated Water and Steam** table to obtain the enthalpy and entropy values at  $P_2 = 90\text{psia}$  and determine the quality at State 2 for isentropic expansion.

$$s_2 = s_1 = 1.567 \frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{R}}$$

$$\chi_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{1.567 \frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{R}} - 0.4643 \frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{R}}}{1.1474 \frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{R}}} = 0.961$$

Use the quality to find the *ideal* enthalpy at State 2.

$$h_2 = h_f + \chi_2 h_{fg} = 290.76 \frac{\text{Btu}}{\text{lb}} + (0.961) \left( 894.9 \frac{\text{Btu}}{\text{lb}} \right) = 1150.7 \frac{\text{Btu}}{\text{lb}}$$

The efficiency is the *actual* change in enthalpy compared with the *ideal* difference in enthalpy for an isentropic process across the same pressure range. Calculate the efficiency.

$$\eta = \frac{h_1 - h_2'}{h_1 - h_2}$$
$$\eta = \frac{1389 \frac{\text{Btu}}{\text{lb}} - 1229.3 \frac{\text{Btu}}{\text{lb}}}{1389 \frac{\text{Btu}}{\text{lb}} - 1150.7 \frac{\text{Btu}}{\text{lb}}} = 0.67$$

**Answer B**