Given:

A piston cylinder device contains 10 1bm of steam at 60 psia and 320 °F. Heat is now transferred to the steam until the temperature reaches 400 °F.

Required:

Assuming the mass of the piston and the atmospheric pressure remain constant, determine the work done by the steam during the heating process.

Solution:

The mass, pressure, and the initial temperature of the steam in the piston cylinder are defined below.

$$m := 10 \text{ lbm}$$

$$P_o := 60 \text{ psi}$$

$$P_0 := 60 \text{ psi}$$
 $T_1 := 320 \text{ °F} = 779.7 \text{ °Ra}$

The final temperature is defined as

$$T_2 := 400 \text{ °F} = 859.7 \text{ °Ra}$$

Boundary work is given by

$$W_b = \int_{1}^{2} P \, \mathrm{d} V$$

Since the pressure is assumed to remain constant throughout the process (i.e., an isobaric process), the boundary work expression becomes

$$W_b = P_0 \cdot \int_{1}^{2} 1 \, dV \qquad W_b = P_0 \cdot (V_2 - V_1)$$

Realizing that the mass remains constant, the boundary may be expressed as

$$W_b = P_0 \cdot m \cdot (v_2 - v_1)$$

Going to Table A-5E @ $P := P_0 = 60 \text{ psi shows}$

$$T_{sat} := 292.69 \text{ °F} = 752.4 \text{ °Ra}$$

Since both T_1 and T_2 are greater than the saturation temperature at P_0 , state 1 and 2 are superheated. Going to

Table A-6E @ $P := P_0 = 60 \text{ psi}$ and $T := T_1 = 320 \text{ °F}$ shows

$$v_1 := 7.4863 \frac{\text{ft}^3}{1 \text{bm}}$$

Going to Table A-6E @ $P := P_0 = 60 \text{ psi}$ and $T := T_2 = 400 \text{ °F}$ shows

$$v_2 := 8.3548 \frac{\text{ft}^3}{1\text{bm}}$$

Thus the boundary work done by the process is

$$W_b := P_0 \cdot m \cdot (v_2 - v_1) = 75040 \text{ ft lbf}$$

$$W_b = 96.43 \text{ BTU}$$