Given:

A piston cylinder device contains $10\ \text{lbm}$ of steam at $60\ \text{psi}$a and $320\ ^\circ\text{F}$. Heat is now transferred to the steam until the temperature reaches $400\ ^\circ\text{F}$.

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.

$$m := 10\ \text{lbm} \qquad P_0 := 60\ \text{psi} \qquad T_1 := 320\ ^\circ\text{F} = 779.7\ ^\circ\text{Ra}$$

The final temperature is defined as

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

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

$$W_b = P_0 \cdot \int_1^2 1\ \mathrm{d}\ V \qquad W_b = P_0 \cdot \left(V_2 - V_1 \right)$$

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

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

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

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

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 $T := T_1 = 320\ ^\circ\text{F}$ shows

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

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

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

Thus the boundary work done by the process is

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

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