Given:

A piston cylinder device contains 10 lbm 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.

$$m := 10\text{lbm} \qquad P_0 := 60\text{psi} \qquad T_1 := 320\,°\text{F} = 779.67\cdot\text{R}$$

The final temperature is defined as

$$T_2 := 400\,°\text{F} = 859.67\cdot\text{R}$$

Boundary work is given by

$$W_b = \int_1^2 P\,dV$$

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

$$W_b = \int_1^2 P\,dV = P_0\cdot\int_1^2 1\,dV = P_0\cdot\left(V_2 - V_1\right)$$

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

$$W_b = P_0\cdot m\cdot\left(\nu_2 - \nu_1\right)$$

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

$$T_{sat} := 292.69\,°\text{F} = 752.36\cdot\text{R}$$

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 @ $P := P_0 = 60\cdot\text{psi}$ and $T := T_1 = 320\cdot°\text{F}$ shows

$$\nu_1 := 7.4863\,\frac{\text{ft}^3}{\text{lbm}}$$

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

$$\nu_2 := 8.3548\,\frac{\text{ft}^3}{\text{lbm}}$$

Thus the boundary work done by the process is

$$\boxed{W_b := P_0\cdot m\cdot\left(\nu_2 - \nu_1\right) = 75038\cdot\text{ft}\cdot\text{lbf}}$$

$$\boxed{W_b = 96.43\cdot\text{Btu}}$$