

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.

$$m := 10 \text{ lbm} \quad P_0 := 60 \text{ psi} \quad T_1 := 320 \text{ °F} = 779.7 \text{ °Ra}$$

The final temperature is defined as

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

Boundary work is given by

$$\bar{W}_b = \int_1^2 P \, dV$$

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

$$\bar{W}_b = P_0 \cdot \int_1^2 1 \, dV \quad \bar{W}_b = P_0 \cdot (V_2 - V_1)$$

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

$$\bar{W}_b = P_0 \cdot m \cdot (v_2 - v_1)$$

Going to Table A-5E @ $T := T_1 = 320 \text{ °F}$ shows

$$P_{sat} := 89.667 \text{ psi}$$

Since both $P_{sat} > P_0$ the state is superheated. Going to Table A-6E @ $P := P_0 = 60 \text{ psi}$ and $T := T_1 = 320 \text{ °F}$ shows

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

The process may be repeated for state 2. Going to Table A-5E @ $T := T_2 = 400 \text{ °F}$ shows

$$P_{sat} := 247.26 \text{ psi}$$

Since both $P_{sat} > P_0$ the state is superheated. Going to Table A-6E @ $P := P_0 = 60 \text{ psi}$ and $T := T_2 = 400 \text{ °F}$ shows

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

Thus the boundary work done by the process is

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

$$\bar{W}_b = 96.43 \text{ BTU}$$