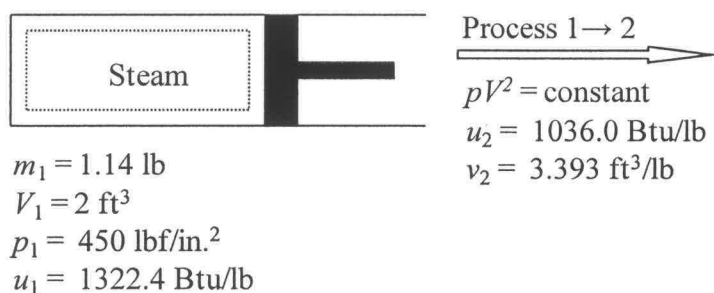


PROBLEM 2.66

Known: Steam in a piston-cylinder assembly undergoes a polytropic process. Initial and final state property data is specified.

Find: Determine the initial specific volume, in ft^3/lb , and the work and heat transfer, each in Btu.

Schematic and Given Data:



Engineering Model:

- (1) The steam within the piston-cylinder arrangement is a closed system.
- (2) Kinetic and potential energy effects are negligible.
- (3) The process is polytropic with $n = 2$.

Analysis:

The initial volume and mass are known, therefore specific volume is found using

$$v_1 = \frac{V_1}{m} = \frac{2 \text{ ft}^3}{1.14 \text{ lb}} = 1.7544 \frac{\text{ft}^3}{\text{lb}} \quad \leftarrow$$

To evaluate W , in Btu, begin with Eq. 2.17, and integrate to obtain Eq. (1) in the analysis of Example 2.1, as can be verified. Then,

$$W = m \left(\frac{p_2 v_2 - p_1 v_1}{1 - n} \right)$$

$$p_2 = \frac{p_1 V_1^2}{V_2^2} = \frac{p_1 V_1^2}{(m v_2)^2} = 120.31 \frac{\text{lbf}}{\text{in.}^2}$$

$$\textcircled{\#1} \quad W = 1.14 \text{ lb} \left(\frac{[(120.31)(3.393) - (450)(1.7544)] \frac{\text{lbf} \cdot \text{ft}^3}{\text{in.}^2 \cdot \text{lb}}}{1 - 2} \right) \left(\frac{1 \text{ Btu}}{778 \text{ ft} \cdot \text{lbf}} \right) \left(\frac{144 \text{ in.}^2}{1 \text{ ft}^2} \right) = 80.45 \text{ Btu} \quad \leftarrow$$

Determine the Q , in Btu, using the closed system energy balance

$$\Delta KE + \Delta PE + \Delta U = Q - W$$

$$Q = \Delta U + W = m(u_2 - u_1) + W = (1.14 \text{ lb})(1036.0 - 1322.4) \frac{\text{Btu}}{\text{lb}} + (80.45 \text{ Btu}) =$$

$$\textcircled{\#2} \quad Q = (-326.5 + 80.45) \text{ Btu} = -246 \text{ Btu} \quad \leftarrow$$

1. The increase in volume for this expansion process is consistent with the positive sign for work, denoting energy transfer out of the system by work.
2. The negative quantity for Q denotes an energy transfer out of the system by heat.