KNOWN: A closed system undergoes a cycle consisting of three processes.

FIND: Sketch the cycle on a p-V diagram and calculate the net work for the cycle and the heat transfer for process 2-3.

SCHEMATIC & GIVEN DATA: The following data are given for each process:
- Process 1-2: Adiabatic compression with \( pV^{1.4} \) const. From \( p_1 = 50 \text{ lb/ft}^2 \), \( V_1 = 3 \text{ ft}^3 \) to \( V_2 = 1 \text{ ft}^3 \)
- Process 2-3: Constant volume
- Process 3-1: Constant pressure, \( U_1 - U_3 = 46.7 \text{ Btu} \)

ASSUMPTIONS: (1) The system is closed. (2) Kinetic and potential energy effects are negligible. (3) Process 1-2 is polytropic.

ANALYSIS:
(a) Since process 1-2 is a polytropic compression, the p-V diagram for the cycle is

(b) Use Eq. 2.17 to evaluate the work for process 1-2:
\[
W_{12} = \int_{V_1}^{V_2} p \, dV = \text{const.} \int_{V_1}^{V_2} \frac{dV}{V^{1.4}} = p_1 V_1^{1.4} \left( \frac{V_2^{1.4} - V_1^{1.4}}{2^{1.4}} \right)
\]
\[
= \left( 50 \frac{\text{lb}}{\text{in}^2} \right) (3 \text{ ft}^3)^{1.4} \left[ \frac{(1 \text{ ft}^3)^{1.4} - (3 \text{ ft}^3)^{1.4}}{2^{1.4}} \right] \left( \frac{144 \text{ in}^2}{1 \text{ ft}^2} \right) \left( \frac{1 \text{ Btu}}{778 \text{ ft} \cdot \text{lb}} \right) = -38.3 \text{ Btu}
\]
For process 2-3: \( W_{23} = 0 \)

Finally, for process 3-1 use Eq. 2.17:
\[
W_{31} = \int_{V_3}^{V_1} p \, dV = p_1 (V_1 - V_3)
\]
\[
W_{31} = (50 \frac{\text{lb}}{\text{in}^2}) (3 - 1) \text{ ft}^3 \left( \frac{144 \text{ in}^2}{1 \text{ ft}^2} \right) \left( \frac{1 \text{ Btu}}{778 \text{ ft} \cdot \text{lb}} \right) = +18.51 \text{ Btu}
\]
Thus \( W_{\text{cycle}} = W_{12} + W_{23} + W_{31} = -19.79 \text{ Btu} \)

(c) For the overall cycle:
\[
Q_{\text{cycle}} = W_{\text{cycle}}
\]
\[
Q_{12} + Q_{23} + Q_{31} = W_{\text{cycle}}
\]
\[
Q_{23} = W_{\text{cycle}} - Q_{31}
\]
For process 3-1: \( \Delta K + \Delta P + (U_1 - U_3) = Q_{31} - W_{31} \Rightarrow Q_{31} = U_1 - U_3 + W_{31}
\]
\[
Q_{31} = 46.7 + 18.51 = +65.21 \text{ Btu}
\]
Finally \( Q_{23} = W_{\text{cycle}} - Q_{31} = -19.79 - 65.21 = -85 \text{ Btu} \)