PROBLEM 2.33

KNOWN: Carbon monoxide gas within a piston-cylinder assembly undergoes three processes in series.

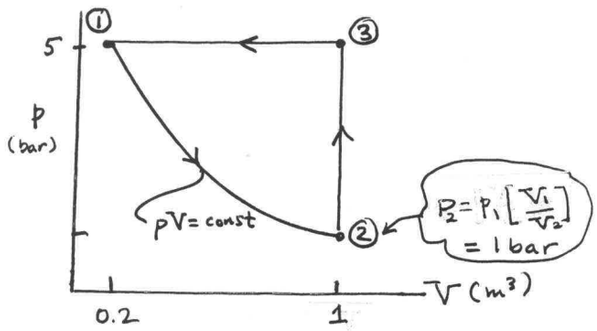
FIND: Sketch the processes in series on a p-V diagram and evaluate the work for each.

Schematic & Given Data:

Process 1–2: Expansion from $p_1 = 5$ bar, $V_1 = 0.2$ m^3 to $V_2 = 1$ m^3, during which the pressure-volume relationship is $pV = constant$.

Process 2–3: Constant-volume heating from state 2 to state 3, where $p_3 = 5$ bar.

Process 3–1: Constant-pressure compression to the initial state.



ENGR. MODEL:

1. The gas is the closed system. 2. Volume change is the only work mode.
3. Each of the three processes is specified.

ANALYSIS: Since volume change is the work mode, Eq. 2.17 applies.

Process 1-2: $W_{12} = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{C}{V}\,dV = C \ln \frac{V_2}{V_1} = p_1 V_1 \ln \frac{V_2}{V_1}$

$= (5\text{bar})(0.2\text{m}^3) \ln\left(\frac{1\text{m}^3}{0.2\text{m}^3}\right) \left|\frac{10^5 \text{N/m}^2}{1\text{ bar}}\right| \left|\frac{1\text{kJ}}{10^3 \text{N·m}}\right| = +160.94\text{kJ}$ ←

Process 2-3: The piston does not move (V = constant). Thus, $W_{23} = 0$ ←

Process 3-1: $W_{31} = \int_{V_3}^{V_1} p\,dV = p_3(V_1 - V_3) = 5\text{bar}(0.2 - 1.0)\text{m}^3 \left|\frac{10^5 \text{N/m}^2}{1\text{ bar}}\right| \left|\frac{1\text{kJ}}{10^3 \text{N·m}}\right|$

$= -400\text{kJ}$ ←

(p = constant at p_3)

(1)

1. For the carbon monoxide gas the net work for the three processes is the sum,

$$W_{net} = W_{12} + W_{23} + W_{31} = (+160.94 + 0 + (-400))\text{ kJ}$$

$$= -239.06\text{ kJ}$$

↖ Net energy transfer by work to the gas.