

PROBLEM 2.77

KNOWN: A gas within a piston-cylinder assembly undergoes a thermodynamic cycle consisting of three processes in series.

FIND: Determine Q_{12} , Q_{31} , U_3 . Determine if the cycle can be a power cycle.

SCHEMATIC & GIVEN DATA:

Process 1-2: Compression with $pV = \text{constant}$, $W_{12} = -104 \text{ kJ}$,

$U_1 = 512 \text{ kJ}$, $U_2 = 690 \text{ kJ}$

Process 2-3: $W_{23} = 0$, $Q_{23} = -150 \text{ kJ}$

Process 3-1: $W_{31} = +50 \text{ kJ}$



ENGR. MODEL:

1. The gas is the closed system.
2. Volume change is the only work mode.
3. For each process, $\Delta KE = \Delta PE = 0$.

ANALYSIS: (a) Process 1-2, $\Delta U + \cancel{\Delta KE} + \cancel{\Delta PE} = Q_{12} - W_{12} \Rightarrow$

$$Q_{12} = [U_2 - U_1] + W_{12} = (690 - 512) \text{ kJ} + (-104 \text{ kJ}) = +74 \text{ kJ}$$

$\leftarrow Q_{12}$

For any cycle, $W_{\text{cycle}} = Q_{\text{cycle}}$ (Eq. 2.40). Thus

$$W_{12} + W_{23} + W_{31} = Q_{12} + Q_{23} + Q_{31}$$

$$\Rightarrow Q_{31} = W_{12} + W_{23} + W_{31} - Q_{12} - Q_{23}$$

$$= (-104) + 0 + 50 - 74 - (-150) = +22 \text{ kJ}$$

$\leftarrow Q_{31}$

Process 3-1: $\Delta U + \cancel{\Delta KE} + \cancel{\Delta PE} = Q_{31} - W_{31} \Rightarrow U_1 - U_3 = Q_{31} - W_{31}$

① $\Rightarrow U_3 = U_1 - Q_{31} + W_{31} = 512 - 22 + 50 = 540 \text{ kJ}$

$\leftarrow U_3$

(b) A power cycle is one for which $W_{\text{cycle}} > 0$. For the current cycle,

$$W_{\text{cycle}} = W_{12} + W_{23} + W_{31}$$

$$= +(-104) + (0) + (50) = -54 \text{ kJ}$$

$\uparrow *$

No. This cycle cannot be a power cycle.

\leftarrow

1. As checks on these calculations, note that

Process 2-3: $(U_3 - U_2) = Q_{23} - W_{23}$

$$= (-150 \text{ kJ}) - 0 \Rightarrow U_3 - U_2 = -150 \text{ kJ}$$

$$\Rightarrow U_3 = 690 - 150 = 540 \text{ kJ}$$

Since U is a property,

$$(U_2 - U_1) + (U_3 - U_2) + (U_1 - U_3) = 0$$

$$(690 - 512) + (U_3 - 690) + (512 - U_3) = 0$$

$$178 + (\overset{540}{-150}) + (\overset{540}{-22}) = 0 \quad \checkmark$$