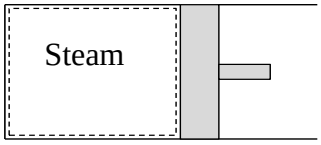
PROBLEM 2.69

Steam in a piston-cylinder assembly undergoes a polytropic process. Data for the initial and final states are given in the accompanying table. Kinetic and potential energy effects are negligible. For the process, determine the work and heat transfer, each in Btu per lb of steam.

State	p (lbf/in.^{2})	v (ft^3/lb)	u (Btu/lb)
1	100	4.934	1136.2
2	40	11.04	1124.2

KNOWN: Steam undergoes a polytropic process in a piston-cylinder assembly. Data are known at the initial and final states.

FIND: Determine the work and heat transfer, each per unit mass of steam.



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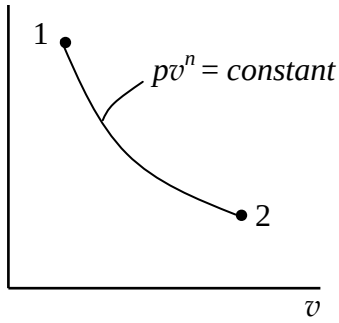

ENGINEERING MODEL: (1) The steam is a closed system. (2) The process is polytropic process, and volume change is the only work mode. (3) Kinetic and potential energy effects are negligible.

ANALYSIS: Since the process is polytropic, Eq 2.17 applies for the work:

$$W/m = \int_{v_1}^{v_2} p\,dv = \int_{v_1}^{v_2} \frac{const}{v^n}\,dv = \frac{(p_2v_2 - p_1v_1)}{1-n}$$

The pressures and specific volumes are known at each state, but n is unknown. To find n, pv^n = *constant* , as follows:

$$p_1v_1^n = p_2v_2^n \quad \rightarrow \quad \frac{p_1}{p_2} = \left(\frac{v_2}{v_1}\right)^n \quad \rightarrow \quad n = \frac{\ln(p_1/p_2)}{\ln(v_2/v_1)} = \frac{\ln(100/40)}{\ln(11.04/4.934)} = 1.1377$$

Thus

$$W/m = \frac{(40\ \text{lbf/in.}^2)(11.04\ \text{ft}^3/\text{lb}) - (100)(4.934)}{1-1.1377}\left|\frac{144\ \text{in.}^2}{1\ \text{ft}^2}\right|\left|\frac{1\ \text{Btu}}{778\ \text{ft·lbf}}\right| = 69.63\ \text{Btu/lb (out)} \longleftarrow$$

The heat transfer is obtained using the energy balance.

PROBLEM 2.69 (CONTINUED)

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

With $\Delta U = m\,\Delta u = m(u_2 - u_1)$

$$Q/m = (u_2 - u_1) + (W/m) = (1124.2 - 1136.2)\ \text{Btu/lb} + (69.63\ \text{Btu/lb})$$

$$= 57.63\ \text{Btu/lb (in)} \longleftarrow$$