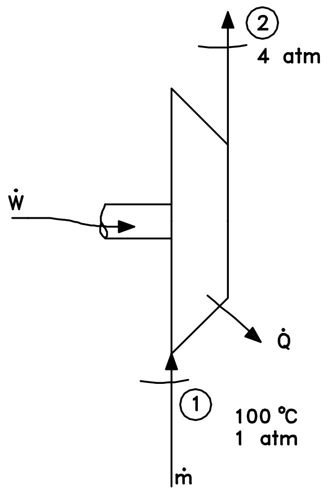
Problem: 8-26

Find: Final temperature and work per unit mass for argon
a) isothermal compression and
b) isentropic compression



a) isothermal case

From the first law:

$$\dot{m}_1(h + pe + ke)_1 + \dot{W} - \dot{Q} = \dot{m}_2(h + pe + ke)_2 + \left.\frac{\partial E}{\partial t}\right|_{CV} \nearrow^{0}$$

$$\dot{m}_1 = \dot{m}_2 = \dot{m} \quad \text{(SF)}$$

Δpe and Δke are negligible, therefore

$$\frac{\dot{W}}{\dot{m}} - \frac{\dot{Q}}{\dot{m}} = h_2 - h_1 \qquad (1)$$

From the second law

$$\dot{P}_s = \left.\frac{ds}{dt}\right|_{CV} \nearrow^{0} + \dot{m}(s_2 - s_1) + \frac{\dot{Q}_{out}}{T} \geq 0$$

For the reversible case:

$$-\frac{\dot{Q}}{\dot{m}} = T(s_2 - s_1) \qquad (2)$$

For a perfect gas:

$$dh = c_p(T)\cancelto{0}{dT}$$

but $dT \to 0$ for the isothermal case, therefore

$$h_2 - h_1 = 0$$

and

$$\begin{aligned}
\frac{\dot{W}}{\dot{m}} = \frac{\dot{Q}}{\dot{m}} &= -T(s_2 - s_1) \\
&= -T\int_1^2 \left[c_p(T)\frac{\cancelto{0}{dT}}{T} - R\frac{dP}{P}\right] \\
&= TR\ln\frac{P_2}{P_1} \\
&= 373.15 \times 0.208 \ln 4 \\
&= \boxed{107.6 \ \ \mathrm{kJ/kg}}
\end{aligned}$$

Note: from Table B.6b - $R = 0.208\ kJ/kg \cdot K$

b) isentropic case

from Problem 8-1

$$\begin{aligned}
T_2 &= T_1\left(\frac{P_2}{P_1}\right)^{R/c_p} \\
&= 373.15(4/1)^{0.208/0.523} \\
&= \boxed{647.6\ K}
\end{aligned}$$

From Eq. 2, $\dot{Q} = 0$ for the isentropic case, therefore

$$\begin{aligned}
\frac{\dot{W}}{\dot{m}} &= h_{2s} - h_1 \\
&= c_p(T_{2s} - T_1) \\
&= 0.523(647.6 - 373.15) \\
&= \boxed{143.6\ kJ/kg}
\end{aligned}$$

Therefore, isentropic compression requires 33.5% more energy input.