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H31 熱力学

[1] (1) $pV = mRT$ より $m = \frac{pV}{RT}$

$$m = \frac{P_1 V_1}{RT_1} = \frac{400 \times 1}{0.25 \times 500} = 3.2 \text{ kg}$$

(2) 等圧変化より $\frac{T_1}{V_1} = \frac{T_2}{V_2}$ より

$$T_2 = \frac{V_2}{V_1} T_1 = \frac{2}{1} \cdot 500 = 1000$$

$$W = 400 (2 - 1) = 400 \text{ kJ}$$

ここで $k = \frac{C_p}{C_v}$, $C_p - C_v = R$ より

$$C_p = \frac{kR}{k-1}, \quad C_v = \frac{R}{k-1}$$

$$= 0.875 \qquad = 0.625$$

よって

$$Q = mC_p (T_2 - T_1)$$
$$= 1400 \text{ kJ}$$
$$\Delta S = mC_p \ln \frac{T_2}{T_1} = 1.96 \text{ kJ/K}$$

(3) 等温変化

$P_1 V_1 = P_2 V_2$ より

$$P_2 = \frac{V_1}{V_2} P_1 = \frac{1}{4} \times 400 = 100 \text{ kPa}$$

$$W = mRT \ln \frac{V_2}{V_1} = 560 \text{ kJ}$$
$$Q = mRT \ln \frac{V_2}{V_1} = 560 \text{ kJ}$$
$$\Delta S = mR \ln \frac{V_2}{V_1} = 1.12 \text{ kJ/K}$$

(4) $pV^k = (一定)$

$$P_1 V_1^k = P_2 V_2^k = pV^k$$

$$W = \int_1^2 p\,dV = P_1 V_1^k \int_1^2 \frac{dV}{V^k} = P_1 V_1^k \frac{1}{1-k} \left(V_2^{\frac{1}{k-1}} - V_1^{\frac{1}{k-1}} \right)$$
$$= \frac{P_1 V_1^k}{k-1} \left(V_1^{\frac{1}{k-1}} - V_2^{\frac{1}{k-1}} \right)$$
$$= 230 \text{ kJ}$$

$Q = 0$, $\Delta S = 0$.

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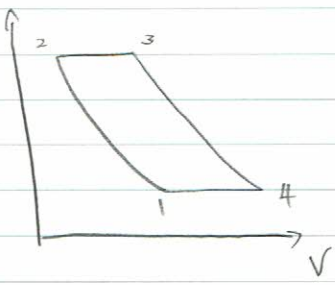
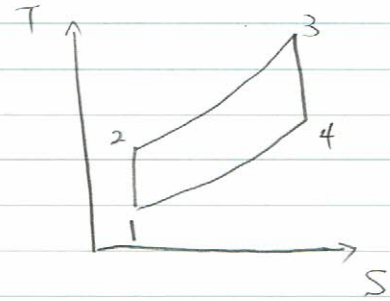
[2] (1)





(2)

$$Q_{23} = mC_p(T_3 - T_2)$$
$$Q_{41} = mC_p(T_4 - T_1)$$

(3) $\frac{C_p}{C_v} = k$, $\varphi = \frac{P_2}{P_1}$, $\alpha = \frac{V_3}{V_2}$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \varphi^{\frac{k-1}{k}}$$

より

$$T_3 = \frac{V_3}{V_2} T_2 = \alpha T_2 = \alpha \varphi^{\frac{k-1}{k}} T_1$$

より

$$T_4 = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \times T_3 = \frac{T_1 \alpha \varphi^{\frac{k-1}{k}}}{\varphi^{\frac{k-1}{k}}} = T_1 \alpha$$

(4)

$$\eta_{th} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{T_1\left(T_4/T_1 - 1\right)}{T_2\left(T_3/T_2 - 1\right)}$$
$$= 1 - \frac{1}{\varphi^{\frac{k-1}{k}}}$$

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[3] 等エントロピー流れ．全エンタルピー一定

(1)

$$h_1 + \frac{w_1^2}{2} = h_2 + \frac{w_2^2}{2}$$

ここで $w_1 = 0$ より

$$w_2^2 = 2(h_1 - h_2)$$

$$w_2 = \sqrt{2(h_1 - h_2)}$$

(2) $$h_1 - h_2 = c_p(T_1 - T_2) = \frac{kR}{k-1}(T_1 - T_2)$$

(3)

$$P_c = P_1\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

$$P_0 = P\left(1 + \frac{k-1}{2}M^2\right)^{\frac{k}{k-1}}$$

$M = 1$ のとき 臨界圧力 となる

$$P_c = P_1\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

(4)

$$P_c = 0.25\times10^3\left(\frac{2}{1.4+1}\right)^{\frac{1.4}{0.4}} = 132\ \mathrm{kPa} = 0.132\ \mathrm{MPa}$$

よって $P_c > P_2$ なり 失細ノズルだと 音速になり 臨界

よって 末広ノズルを用いるべき