Τυπολόγιο Θερμοδυναμικής

Γενικές Σχέσεις

$$\alpha := \frac{A}{m} \qquad \dot{A} \equiv \frac{A}{t}$$

(A= τυχαίο μέγεθος)

$$Q_{12} = m\int_1^2 c\,dT \overset{c=\text{σταθ.}}{=} mc(T_2 - T_1) \qquad c_p = \left(\frac{\partial q}{\partial T}\right)_p \qquad c_V = \left(\frac{\partial q}{\partial T}\right)_V \qquad W_{V12} = -\int_1^2 p\,dV$$

$$w_{\mu 12} = (\varepsilon_{K2} - \varepsilon_{K1}) + (\varepsilon_{\Delta 2} - \varepsilon_{\Delta 1}) \qquad W_{\rho 12} = p_2V_2 - p_1V_1 \qquad w_{t12} = w_{V12} + w_{\rho 12} + (\varepsilon_{K2} - \varepsilon_{K1}) + (\varepsilon_{\Delta 2} - \varepsilon_{\Delta 1}) + w_{R12} \qquad h = u + pv$$

$$w_{V12} + w_{\rho 12} = \int_1^2 v\,dp \qquad P = \frac{dW_t}{dt} \overset{\text{ομαλή λειτουργία}}{=} \frac{W_t}{t} \overset{\text{σταθερή ροή}}{=} \dot{m}w_t \qquad \oint d\Phi \overset{\text{αν } \Phi = \text{καταστατικό μέγεθος}}{=} 0 \Leftrightarrow \int_1^2 d\Phi = \Phi_2 - \Phi_1$$

1ο Θ.Α.

$$U_2 - U_1 = Q_{12} \underbrace{- \int_1^2 p\,dV}_{W_{V12}} + W_{R12}$$

$$V = \text{σταθ.} \rightarrow Q_{12}^{rev} = U_2 - U_1 \qquad p = \text{σταθ.} \rightarrow Q_{12}^{rev} = H_2 - H_1$$

$$(h_2 - h_1) + (\varepsilon_{K2} - \varepsilon_{K1}) + (\varepsilon_{\Delta 2} - \varepsilon_{\Delta 1}) = q_{12} + w_{t12}$$

$$h_2 - h_1 = q_{12} + \underbrace{\int_1^2 v\,dp}_{w_{V12}+w_{\rho 12}} + w_{R12}$$

$$-W_{o\lambda} \overset{\text{κύκλος}}{=} Q_{o\lambda}$$

$$S_2 - S_1 \overset{T_1=T_2=T}{=} \frac{Q_{12}}{T}$$

2ο Θ.Α.

$$dS = \frac{dQ^{rev}}{T} = \frac{dQ}{T} + \frac{dW_R}{T} \qquad \oint dS = 0 \qquad \oint \frac{dQ}{T} \le 0 \qquad \Delta S_{\text{αδιαβατικό ή αποκλεισμένο}} \ge 0 \qquad dS = \frac{dU + p\,dV}{T} = \frac{H - V\,dp}{T}$$

Ιδανικά αέρια

$$pV = nRT = mR_mT \qquad U_2 - U_1 = nC_V(T_2 - T_1) \qquad H_2 - H_1 = nC_p(T_2 - T_1)$$

$$Q_{12} = nC_V(T_2 - T_1) + \int_1^2 p\,dV = nC_p(T_2 - T_1) - \int_1^2 V\,dp \qquad \int_1^2 p\,dV \overset{T_1=T_2=T}{=} nRT\ln\frac{V_2}{V_1} \qquad \int_1^2 V\,dp \overset{T_1=T_2=T}{=} nRT\ln\frac{p_2}{p_1}$$

$$S_2 - S_1 = nC_V\ln\frac{T_2}{T_1} + nR\ln\frac{V_2}{V_1} = nC_p\ln\frac{T_2}{T_1} - nR\ln\frac{p_2}{p_1} \qquad \frac{T_1}{T_2} \overset{\text{πολυτροπική διεργασία}}{=} \left(\frac{V_2}{V_1}\right)^{\kappa-1} = \left(\frac{p_1}{p_2}\right)^{\frac{\kappa-1}{\kappa}}$$

$$W_{V12} \overset{\text{πολυτροπική διεργασία}}{=} nC_V\frac{\gamma-1}{\kappa-1}(T_2 - T_1) = nC_p\frac{\gamma-1}{(\kappa-1)\gamma}(T_2 - T_1) = \frac{1}{\kappa-1}p_1V_1\left(\frac{T_2}{T_1} - 1\right) \overset{\text{αν } d\varepsilon_K = d\varepsilon_\Delta = 0}{=} \frac{W_{t12}}{\kappa} = \frac{\gamma-1}{\kappa-\gamma}Q_{12}$$

$$R = C_p - C_V = 8,314\ J/(mol\,K) \qquad R_m = c_p - c_V = \frac{R}{M}$$

$$\gamma = \frac{c_p}{c_V} \qquad \kappa = \frac{c_p - c}{c_V - c} \qquad c = c_V\frac{\kappa - \gamma}{\kappa - 1}$$

Carnot

$$T_1 > T_2 \qquad Q_1 \equiv Q^{\text{ορθός}}_{\text{προσδιδόμενη}} \qquad Q_2 \equiv \left|Q^{\text{ορθός}}_{\text{απαγόμενη}}\right|$$

$$n_\theta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} \qquad \varepsilon_\psi = \frac{Q_2}{\underbrace{Q_1 - Q_2}_{W_t}} = \frac{T_2}{T_1 - T_2} \qquad \varepsilon_{\alpha\theta} = \frac{Q_1}{\underbrace{Q_1 - Q_2}_{W_t}} = \frac{T_1}{T_1 - T_2}$$

Συμπιεστές

$$W_t = \frac{\kappa}{\kappa-1}p_1V_{\text{αναρροφόμ.}}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} - 1\right] \qquad \varepsilon_o = \frac{V_{\text{επιζ.}}}{V_h} \qquad n_o = \frac{V_{\text{αναρροφόμ.}}}{V_h} = 1 + \varepsilon_o - \frac{V_4}{V_h} = 1 - \varepsilon_o\left[\left(\frac{p_2}{p_1}\right)^{\frac{1}{\kappa}} - 1\right]$$

V_4 : έναρξη αναρρόφησης

$$\frac{p_\mu}{p_1} = \sqrt{\frac{p_2}{p_1}} \qquad W_t = \frac{\kappa}{\kappa-1}p_1V_{\text{αναρρ.}}\left[\left(\frac{p_\mu}{p_1}\right)^{\frac{\kappa-1}{\kappa}} + \left(\frac{p_2}{p_\mu}\right)^{\frac{\kappa-1}{\kappa}} - 2\right] \qquad W_{t\nu} = \nu\frac{\kappa}{\kappa-1}p_1V_{\text{αναρροφ.}}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\nu\kappa}} - 1\right]$$

$$\frac{p_{\mu 1}}{p_1} = \sqrt[\nu]{\frac{p_2}{p_1}} \qquad P = \frac{W_t}{t} = \dot{m}w_t$$

$V_{\text{αναρροφ.}} \equiv$ όγκος αναρροφόμενου αέρα
$p_1 \equiv$ πίεση εισόδου, $p_2 \equiv$ πίεση εξόδου

$$n_\pi = \frac{P_{is}}{P_i} \qquad n_m = \frac{P_i}{P_e} \qquad n_{o\lambda} = n_\pi n_m$$

Θερμικές Μηχανές

$$n_\theta = \frac{W_t}{Q} = \frac{P_t}{\dot{Q}} \qquad n_i = \frac{W_i}{Q} = \frac{P_i}{\dot{Q}} \qquad n_\pi = \frac{W_i}{W_t} = \frac{P_i}{P_t} = \frac{n_i}{n_\theta} \qquad n_m = \frac{W_e}{W_i} = \frac{P_e}{P_i} \qquad n_{o\lambda} = \frac{W_e}{Q} = \frac{P_e}{\dot{Q}} = n_\theta n_\pi n_m = n_i n_m$$

Joule Ericson

$1 \rightarrow 2$: είσοδος $\rightarrow$ έξοδος συμπιεστή

$$n_\theta^J = 1 - \frac{T_1}{T_2} = 1 - \left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}} = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

3 : είσοδος στροβίλου

$$W_t^J = Q_{23}n_\theta \qquad \alpha_\varepsilon = 1 - \frac{T_1}{T_3}\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}} \qquad n_\theta^E = 1 - \frac{T_1}{T_3} \qquad W_t^E = -nR(T_3 - T_1)\ln\frac{p}{p_0}$$

ΜΕΚ

$$\varepsilon = \frac{V_1}{V_2} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}} \qquad \varphi = \frac{V_3}{V_2} \qquad \psi = \frac{p_3}{p_2} \qquad n_\theta^O = 1 - \frac{T_1}{T_2} \qquad n_\theta^D = 1 - \frac{1}{\gamma}\frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{1}{\gamma\varepsilon^{\gamma-1}}\frac{\varphi^\gamma - 1}{\varphi - 1}$$

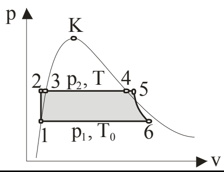
V_1 : όγκος κυλίνδρου, V_2 : επιζήμιος χώρος

$$n_\theta^S = 1 + \frac{T_1 - T_5}{T_3 - T_2 + \gamma(T_4 - T_3)} = 1 - \frac{1}{\varepsilon^{\gamma-1}}\frac{\psi\varphi^\gamma - 1}{\psi - 1 + \gamma\psi(\varphi - 1)}$$

Τυπολόγιο Θερμοδυναμικής

Ατμοί	$\alpha \equiv v,u,h,s$	$x = \frac{m''}{m} = \frac{\alpha - \alpha'}{\alpha'' - \alpha'}$	$\alpha = \alpha' + x(\alpha'' - \alpha')$	$p = \sigma\tau\alpha\theta. \rightarrow \alpha_2 - \alpha_1 = (x_2 - x_1)(\alpha'' - \alpha')$	$m' = (1-x)m$

$q_{\alpha\iota\sigma\theta} = h' - h_0 \approx h'$	$r = h'' - h' = T(s'' - s')$	$\mu = \left(\frac{\partial T}{\partial p}\right)_h$	$dp = 0 \rightarrow q_{12} = h_2 - h_1$ $dv = 0 \rightarrow q_{12} = u_2 - u_1$	$ds = 0 \xrightarrow{\Delta\varepsilon_K = \Delta\varepsilon_\Delta \cong 0} w_{t12} = h_2 - h_1$

Clausius-Rankine	$n_\theta = 1 - \frac{T_0(s_4 - s_2)}{h_4 - h_2}$	$n_\theta^{\upsilon\pi\varepsilon\rho\theta.} = 1 - \frac{T_0(s_5 - s_2)}{h_5 - h_2}$		$T_\mu = \frac{h_5 - h_2}{s_5 - s_2} = T_6^{\beta\varepsilon\lambda\tau.}$ $T_\mu^{\alpha\nu\alpha\theta.} = \frac{(h_5 - h_2) + (h_7 - h_6)}{s_7 - s_2}$

Ψυκτικοί Κύκλοι	$1 \rightarrow 2$: είσοδος $\rightarrow$ έξοδος συμπιεστή 4 : είσοδος εξατμιστή	$\varepsilon_\psi = \frac{q_0}{w_t} = \frac{h_1 - h_4}{h_2 - h_1}$	$\dot{Q}_0 = \dot{m}_\chi q_0$ $P = P_\chi + P_\upsilon$	$p_\mu = \sqrt{pp_0} \Leftrightarrow \frac{p_\mu}{p_0} = \frac{p}{p_\mu}$	$\beta = \frac{\dot{Q}_0}{\dot{Q}_\delta}$

Μείγματα	$\xi_i = \frac{m_i}{m}$	$\psi_i = \frac{n_i}{n} = \frac{V_i}{V}$	$\sum_i \xi_i = \sum_i \psi_i = 1$	$M = \sum_i \psi_i M_i = \frac{1}{\sum_i \xi_i / M_i}$	$p_i = \psi_i p$	$p = \sum_i p_i$

Ιδανικά	$\frac{V_i}{V} = \psi_i$	$\alpha = \sum_i \xi_i \alpha_i, \quad \alpha \equiv u, h, s, c_p, c_v, R_\mu$	$\Delta s = \sum_i \xi_i R_i \ln\frac{V}{V_i} = -R_\mu \sum_i \psi_i \ln\psi_i$

Αερίων-Ατμών	$p = p_L + p_D$	$x = \frac{m_{H_2O}}{m_L} \overset{x \le x_S}{=} 0{,}622\frac{p_D}{p - p_D}$	$\varphi = \frac{p_D}{p_S} = \frac{x}{0{,}622 + x}\frac{p}{p_S}$	$m_\alpha = (1+x)m_L$	$\xi_{H_2O} = \frac{x}{1+x}$

$\xi_L = \frac{1}{1+x}$	$v_\alpha \overset{x \le x_S}{=} 461{,}5\frac{x + 0{,}622}{x + 1}\frac{T}{p}$	$v_{1+x} = \frac{V_\alpha}{m_L} = (1+x)v_\alpha$	$m_L \overset{x \le x_S}{=} \frac{V}{461{,}5(x + 0{,}622)\frac{T}{p}}$

$h_{1+x} = \frac{H_\alpha}{m_L} = h_L + xh_{H_2O} = h_L + \begin{cases} xh_D, & (\chi\omega\rho\acute{\iota}\varsigma\ \sigma\upsilon\mu\pi.) \\ x_S h_D + (x - x_S)h_\nu, & (\upsilon\gamma\rho\acute{o}\ \sigma\upsilon\mu\pi.) \\ x_S h_D + (x - x_S)h_\pi, & (\sigma\tau\varepsilon\rho\varepsilon\acute{o}\ \sigma\upsilon\mu\pi.) \end{cases}$	$h_L = c_{pL}t$	$h_D = r + c_{pD}t$	$h_\nu = c_\nu t$

$h_\pi = r_\pi + c_\pi t$	$\frac{m_{L2}}{m_{L1}} = \frac{x_1 - x_\mu}{x_\mu - x_2} = \frac{h_{1+x1} - h_{1+x\mu}}{h_{1+x\mu} - h_{1+x2}}$	$(1 \leftrightarrow M) = \frac{(1 \leftrightarrow 2)}{m_{L1}/m_{L2} + 1}$	$x_2 = x_1 + \frac{\Delta m_{H_2O}}{m_L}$

$p = \sigma\tau\alpha\theta. \rightarrow Q_{12} = m_L(h_{1+x2} - h_{1+x1})$	