

Main Thermo Formulas

$$\frac{dm_{cv}}{dt} = \sum_i \dot{m}_i - \sum_e \dot{m}_e \quad (4.6) \quad E_{cv}(t) = \int_V \rho e \, dV = \int_V \rho \left(u + \frac{V^2}{2} + gz \right) dV \quad (4.25)$$

$$\frac{dE_{cv}}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \sum_i \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gz_i \right) - \sum_e \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gz_e \right) \quad (4.24)$$

$$W_{\text{cycle}} \leq 0 \text{ (single reservoir)} \quad (5.1) \quad \left(\frac{Q_C}{Q_H} \right)_{\text{rev cycle}} = \frac{T_C}{T_H} \quad (5.6) \quad \eta_{\text{max}} = 1 - \frac{T_C}{T_H} \quad (5.8)$$

$$\oint \left(\frac{\delta Q}{T} \right)_b = -\sigma_{\text{cycle}} \quad (6.4) \quad T \, dS = dU + p \, dV \quad (6.15) \quad T \, dS = dH - V \, dp \quad (6.16)$$

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T} \right)_b + \sigma \quad (6.31)$$

entropy change entropy transfer entropy production $\sigma \geq 0$
 = 0 for Revers.

$$\frac{dS_{cv}}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e + \dot{\sigma}_{cv} \quad (6.42)$$

rate of entropy change rates of entropy transfer rate of entropy production

$$\left(\frac{\dot{W}_{cv}}{\dot{m}} \right)_{\text{int rev}} = - \int_1^2 v \, dp + \left(\frac{V_1^2 - V_2^2}{2} \right) + g(z_1 - z_2) \quad (6.59)$$

$$\dot{J} = T_0 \dot{G}$$

$$A = (E - U_0) + p_0(V - V_0) - T_0(S - S_0) \quad (7.2) \quad a_f = h - h_0 - T_0(s - s_0) + \frac{V^2}{2} + gz \quad (7.31)$$

$$\frac{dA_{cv}}{dt} = \sum_j \left(1 - \frac{T_0}{T_j} \right) \dot{Q}_j - \left(\dot{W}_{cv} - p_0 \frac{dV_{cv}}{dt} \right) + \sum_i \dot{m}_i a_{fi} - \sum_e \dot{m}_e a_{fe} - \dot{I}_{cv} \quad (7.32)$$

$$\varepsilon = \eta \left(\frac{1 - T_0/T_u}{1 - T_0/T_s} \right) \quad (7.40)$$

General Conservation Law(s)

For any property **P**: mass, energy, entropy, availability....:

$$\left. \frac{\partial P}{\partial t} \right|_{CV} = \overbrace{\frac{\partial}{\partial t} \int_{\text{Control Volume}} p \cdot (\rho dV)}^{\text{Property ACCUMULATION}} = \underline{[\text{CV Accumulation}]_{\text{rate}} =}$$

$$= \underline{[(\text{In-Out})_{CS} + (\text{Production-Distriction})_{\text{Sys}}]_{\text{rate}}}$$

$$\Rightarrow [\text{In-Out}]_{\text{rate}} = \dot{P}_{\text{In-Out}} = \overbrace{- \int_{\text{Control Surface}} \vec{p}_{\text{flux}} \cdot d\vec{A}}^{\text{Property TRANSFER}} - \overbrace{\int_{\text{Control Surface}} p (\rho \vec{U} \cdot d\vec{A})}_{\text{Property TRANSPORT}}$$

\Rightarrow [Accumulation]_{rate} = 0 for a steady flow process

\Rightarrow [(Production-Distriction)]_{rate} = 0 for mass and energy

\Rightarrow [Production = σ]_{rate} ≥ 0 for entropy ; [Prod.= ΣF]_{rate} for momentum

\Rightarrow [Distriction = $I = T_0 \sigma$]_{rate} ≥ 0 for availability (exergy)