Reference Sheet - Basic Equations

Property Evaluation

$$v \;=\; (1-x)v_f \;+\; xv_g\,, \qquad\qquad x \;=\; \frac{m_{vap}}{m_{liq}+m_{vap}}$$

$$c_v \;=\; \left.\frac{\partial u}{\partial T}\right|_v, \qquad c_p \;=\; \left.\frac{\partial h}{\partial T}\right|_p \qquad\qquad h \;=\; u \;+\; pv$$

$$p\,v \;=\; R\,T$$

$$\begin{aligned} Tds &= du \;+\; pdv \\ Tds &= dh \;-\; vdp \\ s_2(T_2,p_2) \;-\; s_1(T_1,p_1) &= s^\circ(T_2) \;-\; s^\circ(T_1) \;-\; R\,ln\frac{p_2}{p_1} \end{aligned}$$

Compression/Expansion Work

$$W \;=\; \int_{\forall_1}^{\forall_2} p\,d\forall$$

Closed System - Conservation of Energy

$$\triangle E \;=\; \triangle U \;+\; \triangle KE \;+\; \triangle PE \;=\; Q_{in} \;+\; W_{in} \;-\; Q_{out} \;-\; W_{out}$$

$$\frac{dE}{dt} \;=\; \dot{Q}_{in} \;+\; \dot{W}_{in} \;-\; \dot{Q}_{out} \;-\; \dot{W}_{out}$$

Control Volume - Conservation of Mass

$$\frac{dm_{CV}}{dt} \;=\; \sum_i \dot{m}_i - \sum_e \dot{m}_e$$

Mass Flow Rate (1D flow)

$$\dot{m} \;=\; \rho AV \;=\; \frac{AV}{v}$$

Control Volume - Conservation of Energy

$$\frac{dE_{CV}}{dt} \;=\; \dot{Q}_{CV,\;in} + \dot{W}_{CV,\;in} + \sum_i \dot{m}_i(h + \frac{V^2}{2} + gz)_i - \dot{Q}_{CV,\;out} - \dot{W}_{CV,\;out} - \sum_e \dot{m}_e(h + \frac{V^2}{2} + gz)_e$$

cont.

Closed System - Entropy Balance

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q_{in}}{T}\right)_b - \int_1^2 \left(\frac{\delta Q_{out}}{T}\right)_b + \sigma$$

Internally Reversible Processes

$$\left(\frac{Q_{net\,in}}{m}\right)_{int\ rev} = \int_1^2 T\,ds\,, \qquad \left(\frac{W_{net\,out}}{m}\right)_{int\ rev} = \int_1^2 p\,dv$$

Control Volume - Entropy Balance

$$\frac{dS_{CV}}{dt} = \sum_j \frac{\dot{Q}_{in,j}}{T_j} - \sum_l \frac{\dot{Q}_{out,l}}{T_l} + \sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e + \dot{\sigma}$$

Isentropic Efficiencies

$$\eta_{turbine} = \frac{(\dot{W}/\dot{m})}{(\dot{W}/\dot{m})_s}\,, \qquad \eta_{compressor} = \frac{(\dot{W}/\dot{m})_s}{(\dot{W}/\dot{m})}\,, \qquad \eta_{pump} = \frac{(\dot{W}/\dot{m})_s}{(\dot{W}/\dot{m})}$$

Internally Reversible, Steady-state Processes

$$\left(\frac{\dot{Q}_{net\,in}}{\dot{m}}\right)_{int\ rev} = \int_1^2 T\,ds\,, \qquad \left(\frac{\dot{W}_{net\,out}}{\dot{m}}\right)_{int\ rev} = -\int_1^2 v\,dp + \left(\frac{V_1^2 - V_2^2}{2}\right) + g(z_1 - z_2)$$

Cycles: Thermal Efficiency, Coefficient of Performance

$$\eta_{th} = \frac{\dot{W}_{net\,out}}{\dot{Q}_{in}}, \qquad \beta_{Ref} = \frac{\dot{Q}_C}{\dot{W}_{in}}, \qquad \beta_{HP} = \frac{\dot{Q}_H}{\dot{W}_{in}}$$

Thermodynamic Temperature Scale

$$\left(\frac{Q_C}{Q_H}\right)_{rev\,cycle} = \frac{T_C}{T_H}$$

Nonreacting Mixtures

$$mf_i = m_i/m, \quad \sum_{i=1}^{j} mf_i = 1, \qquad y_i = n_i/n, \quad \sum_{i=1}^{j} y_i = 1$$

$$\overline{u} = \sum_{i=1}^{j} y_i\,\overline{u}_i, \quad \overline{h} = \sum_{i=1}^{j} y_i\,\overline{h}_i,$$

Reacting Mixtures

$$\overline{h} = \overline{h}_f^\circ + \Delta\overline{h} = \overline{h}_f^\circ + [\overline{h}(T) - \overline{h}(T_{ref})]$$

$$0 = \frac{\dot{Q}_{CV,\ net\,in}}{\dot{n}_F} - \frac{\dot{W}_{CV,\ net\,out}}{\dot{n}_F} + \sum_R n_i(\overline{h}_f^\circ + \Delta\overline{h})_i - \sum_P n_e(\overline{h}_f^\circ + \Delta\overline{h})_e$$