Reference Sheet - Basic Equations

Property Evaluation

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

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

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

$$\begin{aligned} Tds &= du \;+\; pdv \\ Tds &= dh \;-\; vdp \end{aligned}$$

$$s_2(T_2,p_2) \;-\; s_1(T_1,p_1) \;=\; s^\circ(T_2) \;-\; s^\circ(T_1) \;-\; R\,ln\frac{p_2}{p_1}$$

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

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

Internally Reversible Processes

$$\left(\frac{Q}{m}\right)_{int\ rev} = \int_1^2 T\,ds\,, \qquad \left(\frac{W}{m}\right)_{int\ rev} = \int_1^2 p\,dv$$

Control Volume - Entropy Balance

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

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

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