# Typical Control Mass Problem Chart 2

*(Not complete material coverage)*

**State ①**

Normally 3 variables are needed to fully determine it.

2 known intensive variables

(May get away with $T$ only in some approximations, eg, when using saturated values as an approximation for compressed liquids.)

- Tables, eg B.1.1-B.1.4; $pv$ or $Tv$ diagrams; $v = v_f + x\,(v_g - v_f)$ and similar for $u$, $h$, and $s$.
- Ideal gas (applicable?) $pv = RT$ (4 forms) Tables A5-A8 for $u$, $h$, $s$.
- Make do with the formulae for *differences* in intensive variables listed below under "Process"?

Remaining intensive variables $p, T, v, (x,) u, h, s$.

Amount of material: $v = V/m \quad u = U/m \quad h = H/m \quad s = S/m$

**Process**

**C1:** Type of process ($V = C$, $p = C$, $p$ linear in $V$, $pV^n = C$, $T = C$, ${}_1Q_2$ =0, reversible?)

**C2:** Mass: $m_1\,(+m_{\text{added}}) = m_2$

Energy: $E_2 - E_1 = {}_1Q_2 - {}_1W_2 \quad (E = U + KE? + PE?)$

**C3:** ${}_1W_2 = 0$ | $p(V_2 - V_1)$ | $\dfrac{p_1 + p_2}{2}(V_2 - V_1)$ | $\dfrac{p_2V_2 - p_1V_1}{1 - n}$ | $p_1V_1 \ln\left(\dfrac{V_2}{V_1}\right)$ | other?

${}_1Q_2 = [0 \text{ and } S_2 = S_1]$ | $T(S_2 - S_1)$ | other? $\quad {}_1S_{2,\text{gen}} = \Delta S_{\text{net}} = S_2 - S_1 - \dfrac{{}_1Q_2}{T_{\text{surr}}}$

For ideal gases:

$$u_2 - u_1 = \int_1^2 C_v \,\mathrm{d}T \approx C_{v_{\text{ave}}}(T_2 - T_1) \qquad h_2 - h_1 = \int_1^2 C_p \,\mathrm{d}T \approx C_{p_{\text{ave}}}(T_2 - T_1)$$

$$s_2 - s_1 = s_T^0(T_2) - s_T^0(T_1) - R\ln\left(\frac{p_2}{p_1}\right) \approx C_{p_{\text{ave}}}\ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{p_2}{p_1}\right) = \ldots$$

$$\text{Polytropic: } \frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^n = \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}} \qquad \begin{array}{rl} \text{isothermal:} & n = 1 \\ \text{isentropic and } k \text{ constant:} & n = k \end{array} \;?$$

For solids and compressed liquids, *by approximation*, best at constant pressure:

$${}_1Q_2 = m\int_1^2 C_{(p)}\,\mathrm{d}T \approx mC_{(p)_{\text{ave}}}(T_2 - T_1) \qquad s_2 - s_1 \approx C_{(p)_{\text{ave}}}\ln\left(\frac{T_2}{T_1}\right)$$

**State ②**

Same procedures as state ①