# Thermodynamics Review

- Energy Transformation:

  mechanical, thermal, nuclear.

  Mass - kg, pound mass $lb_m$

  Force - $N(kg\frac{m}{s^2})$ pound force $lb_f$

  Temperature - °C, °K, °F, °R

  Energy $J\,(N.m)$ Btu (= 778 ft-$lb_f$).

- Potential Energy

  $$PE = Mgz \quad (N.m)$$

- Kinetic Energy

  $$K.E = M\frac{u^2}{2} \quad (N.m)$$

- Internal Energy

  $$I.E = e, \quad (J/kg)$$

- Flow Energy $= pv = \frac{P}{\rho} \quad \left(\frac{J}{kg}\right)$

- Heat Energy $= Q$ (J)

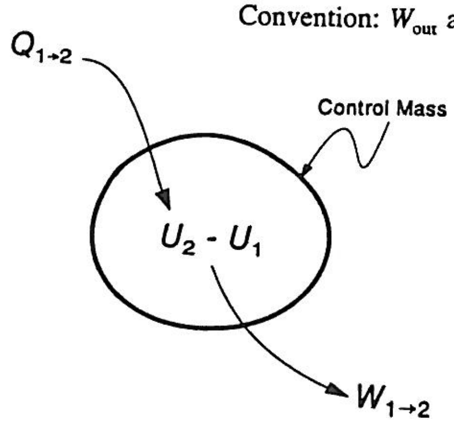
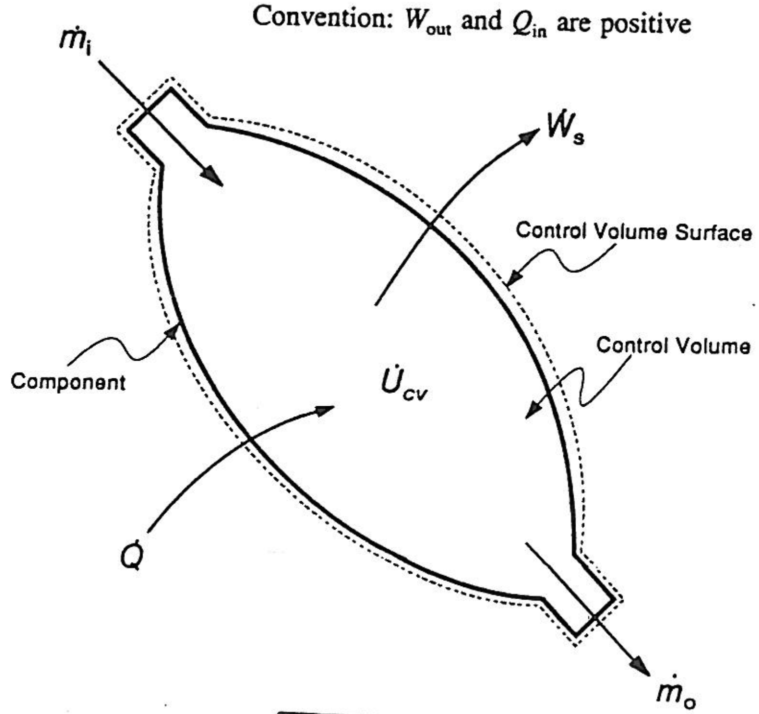
- Work Done:

  e.g.

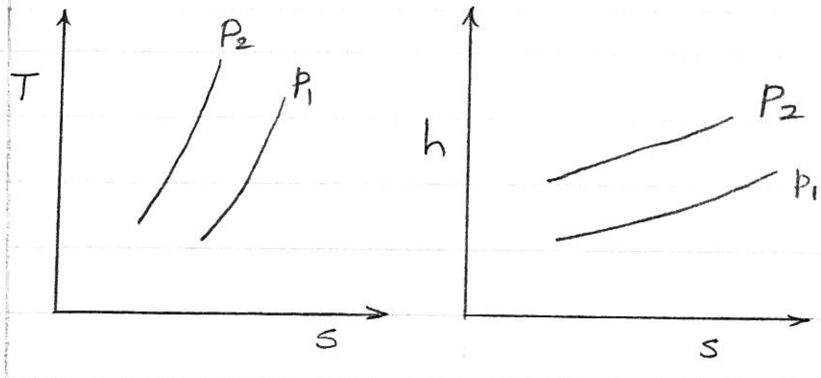
  $dW = \underline{F}.d\underline{x}$ ; $W_{12} = \int_1^2 \underline{F}.d\underline{x}$ - force action

  $dW = \pm P.dV$ - expansion or compression

- Entropy $ds \equiv \frac{dQ_{Rev}}{T}$

| Parameter | First law | Second law |
|---|---|---|
| Control mass | $\dot U^\circ_{\text{c.m.}} = \dot Q_{\text{c.m.}} - \dot W_{\text{c.m.}}$ (Eq. 4-19a)<br>For a process involving finite changes between states 1 and 2, Eq. 4-19a becomes<br>$U_2 - U_1 = Q_{1+2} - W_{1+2}$ (Eq. 6-1)<br>if kinetic energy differences are negligible<br>Convention: $W_{\text{out}}$ and $Q_{\text{in}}$ are positive<br><br> | $\dot S_{\text{c.m.}} = \dot S_{\text{gen}} + \frac{\dot Q_{\text{c.m.}}}{T_s}$ (Eq. 4-25b)<br>where $T_s$ is the temperature at which heat is supplied |
| Control volume (stationary) | $\dot E_{\text{c.v.}} = \sum_{i=1}^{I} \dot m_i (h_i^\circ + gz_i) + \dot Q + \dot Q_{\text{gen}} - \dot W_{\text{shaft}} - \dot W_{\text{normal}} - \dot W_{\text{shear}}$ (Eq. 4-39)<br>Neglecting shear work and differences in kinetic and potential energy, and treating $\dot Q_{\text{gen}}$ as part of $\dot U$, Eq. 4-39 becomes<br>$\dot U_{\text{c.v.}} = \sum_{i=1}^{I} \dot m_i h_i + \dot Q - \dot W_{\text{shaft}} - \dot W_{\text{normal}}$ (Eq. 6-2)<br>Convention: $W_{\text{out}}$ and $Q_{\text{in}}$ are positive<br><br> | $\dot S_{\text{c.v.}} = \sum_{i=1}^{I} \dot m_i s_i + \dot S_{\text{gen}} + \frac{\dot Q}{T_s}$ (Eq. 4-41) |

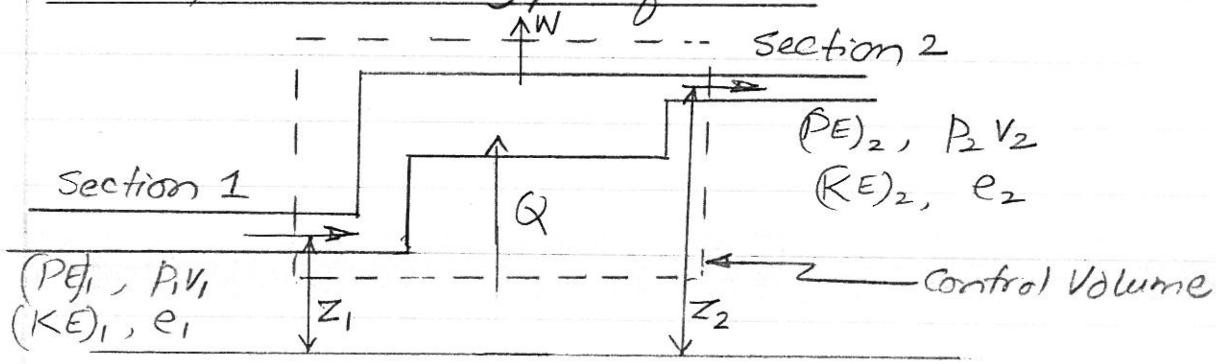
Thermodynamic property diagrams:




$T = T(u, v)$ : $P = P(T, v)$    Equations of State.

$P = P(u, v)$    $u = u(T, v)$

Steady Flow Energy Equation:




Steady condition:

Energy entering = Energy leaving

$$\frac{z_1 g}{J} + \frac{u_1^2}{2J} + e_1 + \frac{P_1 V_1}{J} + Q = \frac{z_2 g}{J} + \frac{u_2^2}{2J} + e_2 + \frac{P_2 V_2}{J} + W.$$

$$h \equiv e + \frac{PV}{J}$$ — enthalpy

$$h_0 \equiv h + \frac{u^2}{2J}$$ — stagnation enthalpy or total enthalpy

$$h_{01} + Q = h_{02} + W$$

For heating process $W \approx 0$,

$$Q = h_{02} - h_{01}$$

For turbines, pumps, compressor $Q \approx 0$

$$W = h_{01} - h_{02}$$

Efficiency – degree of irreversibility.

(1) Pumps or compressor (adiabatic compression)

$$dh + \frac{1}{2J} d(u^2) + \frac{g\,dz}{J} = dQ - dW.$$

$$T\,ds = dh - \frac{V\,dp}{J} \quad \text{– for single component}$$

$$-dW = (T\,ds - dQ) + \frac{V}{J} dp + \frac{d(u^2)}{2J} + \frac{g\,dz}{J}$$

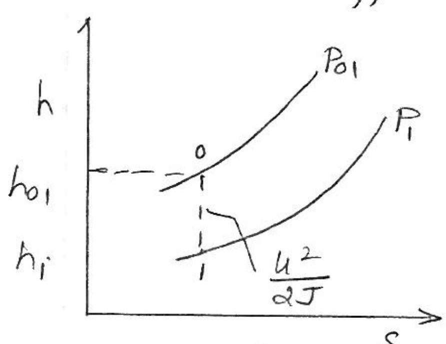
2nd Law: $T\,ds - dQ > 0$

$$\therefore -dW = (+) + \frac{1}{J}\left(V\,dp + \frac{d(u^2)}{2} + g\,dz\right)$$

$$-\int_1^2 dW = -W_p > \frac{1}{J} \int_1^2 \left(V\,dp + \frac{d(u^2)}{2} + g\,dz\right) > \frac{1}{J}(H_2 - H_1)$$

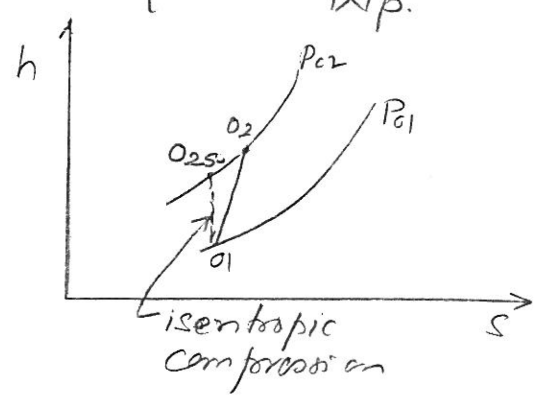
$$H = pv + \frac{u^2}{2} + gz \leftarrow \text{Bernoulli Head.}$$

$$\text{Pump Efficiency} = \eta = \frac{(H_2 - H_1)/J}{W_p} \leftarrow \text{(ideal work)}$$



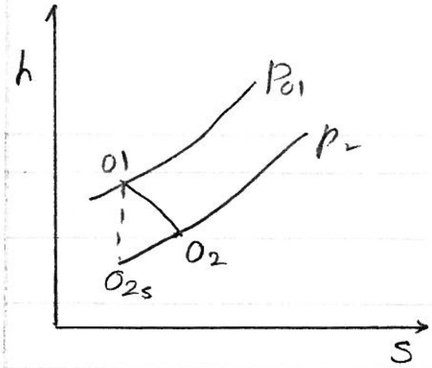

Compression efficiency

$$\eta_c = \frac{h_{01} - h_{02s}}{h_{01} - h_{02}}$$



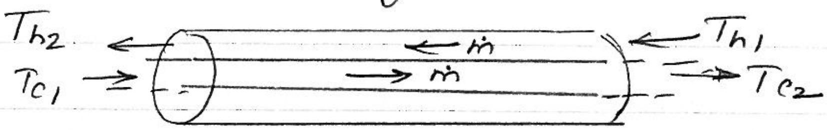
(2) Turbines (Adiabatic Expansion).

Turbine efficiency




$$\eta_t = \frac{h_{01} - h_{02}}{h_{01} - h_{02s}} =$$

(3) Heat Exchangers




$$\eta_x = \frac{T_{c2} - T_{c1}}{T_{h1} - T_{h2}}$$

Theromodynamic Cycles and Their Efficiencies.

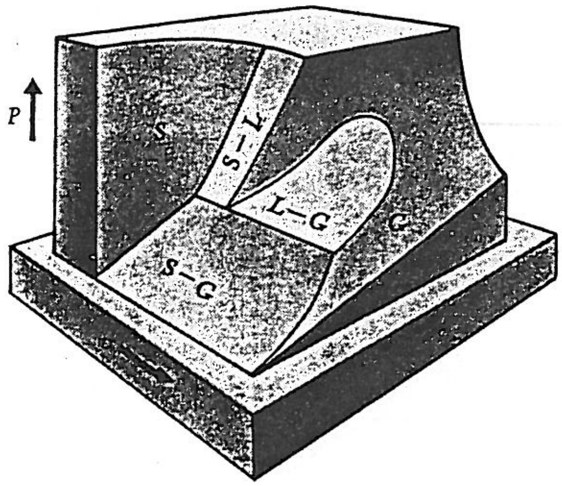



**FIG. 4·3** *P-v-T surface for a substance which expands upon melting*

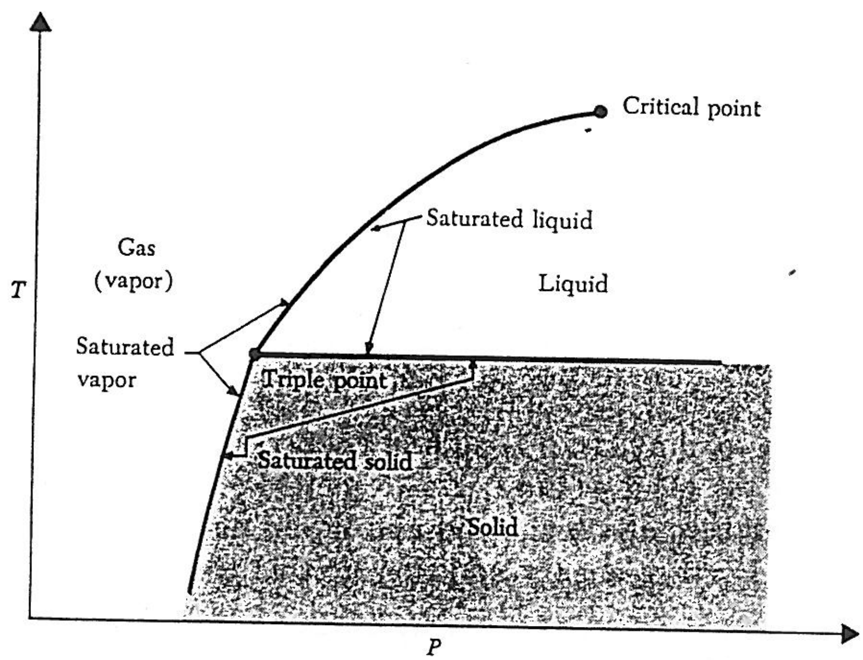



**FIG. 4·4** *A typical T-P diagram*

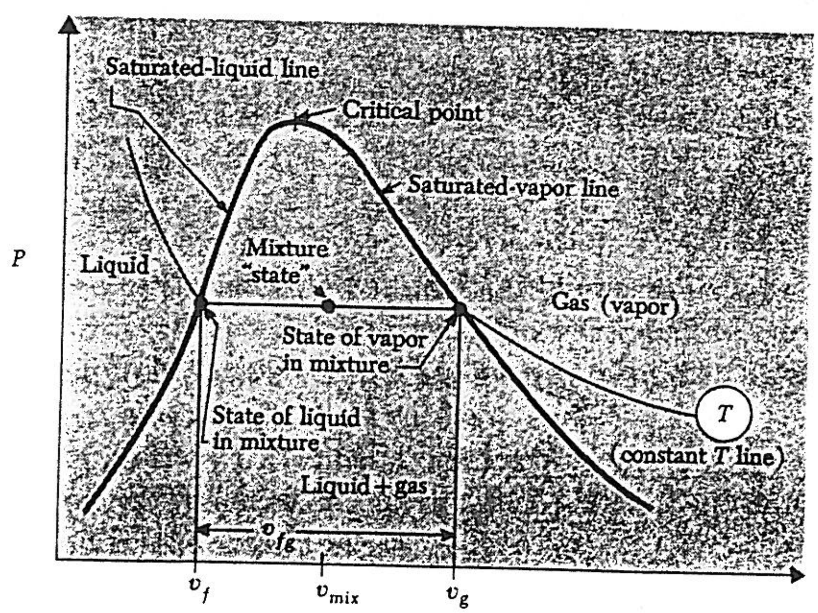



**FIG. 4·5** *The vapor dome on a P-v plane*

24 (7)

Fig. 1. Temperature entropy chart.

Keenan, Keyes, Hill, & Moore
STEAM TABLES (International System of Units S.I.)
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