1st Law: Energy can't be created or destroyed

Energy Balance: $\Delta E_{stored} = E_{in} - E_{out} + E_{gen}$

Rate: $\Delta \dot{E}_{stored} = \dot{E}_{in} - \dot{E}_{out} + \dot{E}_{gen}$

} generally ignore E_{gen}

Energy Transfer by work & heat:

$Q_{out} < 0 \quad W_{in} < 0$

$Q_{in} > 0 \quad W_{out} > 0$

Closed system - fixed mass (subset of open system)
Open System - fixed volume

- Closed system: $\frac{dE_{sys}}{dt} = \dot{Q}_{in,net} - \dot{W}_{out,net}$

$\Delta E_{stored} = Q - W$

$\Delta U + \Delta KE + \Delta PE = Q - W$

Q: light bulb powered by electricity has $-W$ & $-Q$

Work: Boundary work - $W = \int p\,d\forall = m\int p\,dv$ [kJ]

$\forall$ - volume

v - specific volume

Constant Pressure - $W = p\Delta\forall$

Special Cases (Ideal Gas) - $p\forall = mRT$

Constant temp: $W = RT\ln\left(\frac{v_2}{v_1}\right) = RT\ln\left(\frac{P_1}{P_2}\right)$

polytropic: $pv^n = \text{constant}$

$$W = \frac{P_2V_2 - P_1V_1}{1-n}$$

isentropic: $s_2 = s_1 \rightarrow pv^k = \text{const}$

$$W = \frac{P_2V_2 - P_1V_1}{1-k} = \frac{RT_1}{k-1}\left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right)$$

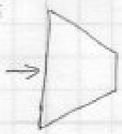
- For boundary work, assume a quasi-equilibrium process exists, which also assume pressure at any instant to be everywhere constant

Open System: $\frac{dE_{cv}}{dt} = \dot{Q} - \dot{W} + \sum \dot{m}_{in}\left(h_{in} + \frac{V_{in}^2}{2} + g z_{in}\right) - \sum \dot{m}_{out}\left(h_{out} + \frac{V_{out}^2}{2} + g z_{out}\right)$

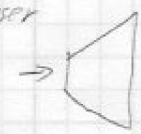
at steady state, $\frac{dE_{cv}}{dt} = 0$

– Nozzle:

$h_{in} + \frac{V_{in}^2}{2} = h_{out} + \frac{V_{out}^2}{2}$



Diffuser



assumptions for nozzle & diffuser

1) adiabatic, $Q = 0$

2) no volume change, $W = 0$

3) Steady state $d/dt = 0$

4) change in potential energy negligible

nozzle efficiency – $\eta = \frac{\Delta h_{actual}}{\Delta h_{ideal}} = \frac{(V_{outlet}^2 - V_{inlet}^2)/2}{(V_{outlet,s}^2 - V_{inlet}^2)/2}$

← isentropic

– Turbines, pumps & compressors

assumptions: 1) adiabatic

2) $d/dt = 0$

3) change in KE & PE negligible

Turbine efficiency

$$\eta_t = \frac{\Delta h_{actual}}{\Delta h_{ideal}}$$

Compressor/Pump efficiency

$$\eta_c = \frac{\Delta h_{ideal}}{\Delta h_{actual}}$$

– Throttling Values

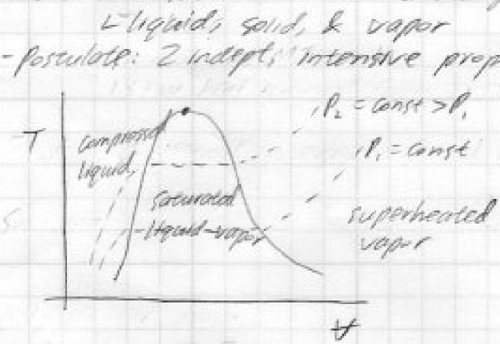
assumptions 1) $Q = 0$

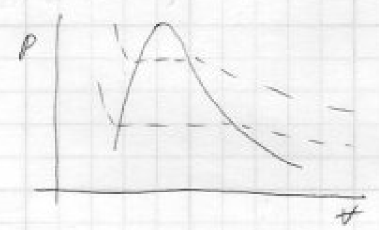
2) $W = 0$

3) $d/dt = 0$

4) ΔKE & ΔPE negligible

Pure Substances - materials with unchanged chem composition
 ↳ liquid, solid, & vapor
 - postulate: 2 indept. intensive properties to fix a state





SLVM: $x = \frac{m_{vap}}{m_{liq} + m_{vap}} = \frac{m_g}{m_f + m_g}$

-Ideal Gases: $P\forall = mRT$
$Pv = RT$
$P = \rho RT$
$P\forall = nR_uT$
$R = \frac{R_u}{MW_{gas}}$

specific heat: $c_p - c_v = R$
internal E: $\Delta u = c_v \Delta T$
entropy: $\Delta s = c_p(T_2/T_1) - R\ln(P_2/P_1)$

-Non-Ideal Gases: $Z = \frac{Pv}{RT} = \frac{P\bar{v}}{R_u T}$

2nd Law: 1) Kelvin-Planck: Impossible to build a cycle engine that have a thermal efficiency of 100%.

2) Clausius: Impossible to devise a cycle that its only effect is to transfer heat from hot to cold

Entropy: $\Delta S \geq \int_{T_1}^{T_2} dQ/T$

$\Delta S = S_2 - S_1 = \frac{Q}{T_0}$ ΔS can be negative

Isentropic: $\Delta S = S_2 - S_1 = 0$

Adiabatic: $\Delta S = S_2 - S_1 \geq 0$

Cycles: Thermal Efficiency

$$\eta = \frac{W_{net}}{Q_{in}} = \frac{W_{out} - W_{in}}{Q_{in}}$$

$$= \frac{Q_{net}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$$

Carnot Cycle: $\eta = \frac{T_H - T_L}{T_H} = 1 - \frac{T_L}{T_H}$

max efficiency $\Rightarrow$ carnot cycle

Rankin Cycle