Review for ME200

Saturday, March 22, 2025 16:28

Steady-State : $0 = \sum_{in} \dot{m}_{in} - \sum_{out} \dot{m}_{out}$

System :
1) closed mass change × work ✓ heat ✓
2) open mass change ✓ work ✓ heat ✓
3) isolated mass change × work × heat ×

Intensive property : P, T, v, u, h, s, x

Extensive property : V, U, H, S

Process : transformation between 2 states

☆ The change between properties is independent to the process
只与状态相关.

Closed system → Lagrangian View → particle tracking / control mass 质量不动.
mass enclosed by a boundary

Open system → Eulerian View → control volume. 质量移动.
volume enclosed by a boundary.

Pressure. 1) Gage pressure : $P_{(gage)} = P_{(absolute)} - P_{atm\,(absolute)}$

2) Vacuum pressure : $P_{(vacuum)} = P_{atm\,(absolute)} - P_{(absolute)}$

Temperature.
$T(°R) = 1.8\,T(K)$
$T(°C) = T(K) - 273.15$
$T(°F) = 1.8\,T(°C) + 32$
$T(°F) = T(°R) - 459.67$

Specific Volume $v = \frac{V}{m} = \frac{1}{\rho}$

Quality (x) $x = \frac{m_{vapor}}{m_{total}}$

Equilibrium: Isolate a system from all surroundings and let it settle to a uniform state — equilibrium state

T 不变 无 W 无 $\dot{m}$

Quasi-Equilibrium : $t_{eq} \ll t_{pr}$ ← 整个 process 的时间 ⇒ Always equilibrium
↑ 系统达到平衡的时间

Work : Done by a system on its surroundings.
$W_{1-2} = \int_1^2 p\,dV$

Ideal Gas : $pV = nRT \Rightarrow pv = RT$
↑ specific volume

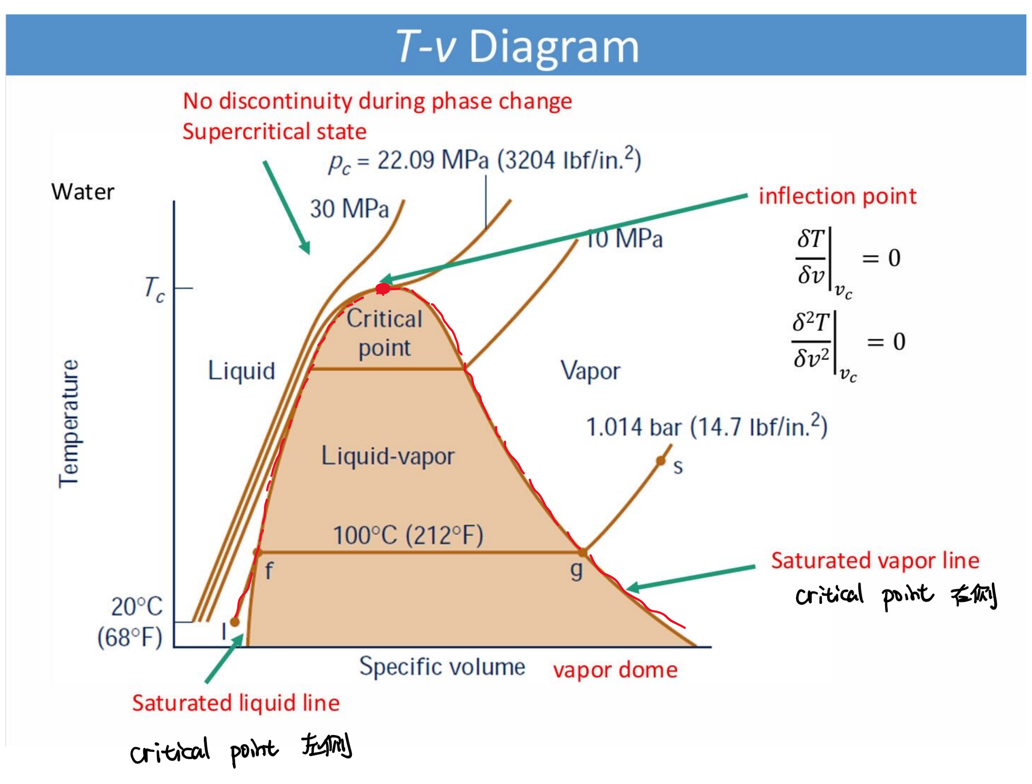
Work Model: $F-x$ $W = \int_1^2 F\,dx$ $\quad \sigma - A$ ($\frac{N}{m}$) $\quad W = \int_1^2 \sigma\,dA$ $\quad p-V$ $\quad W = \int_1^2 p\,dV$

First Law of Thermodynamics.

Energy is Conversed.

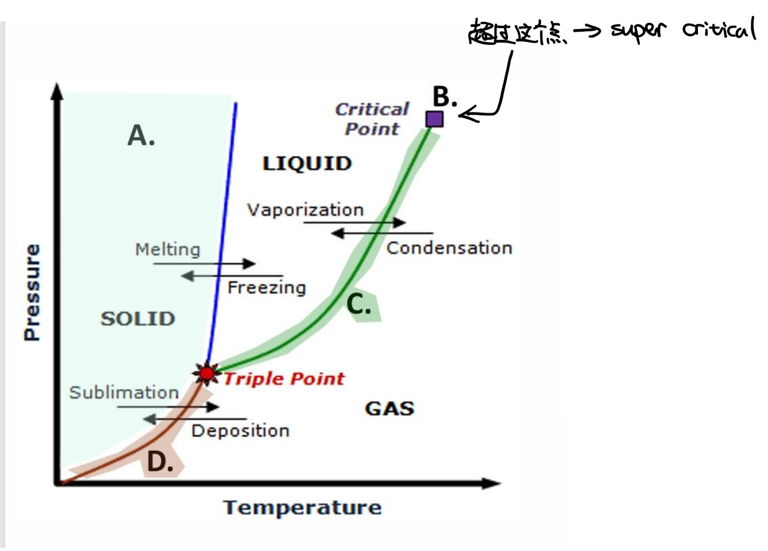
Closed system : $Q_{1-2} - W_{1-2} = E_2 - E_1 = \Delta KE + \Delta PE + \Delta U$

pure : 只有一种物质 Simple: 只有一种形式的 work. Compressible : Only work from compression.

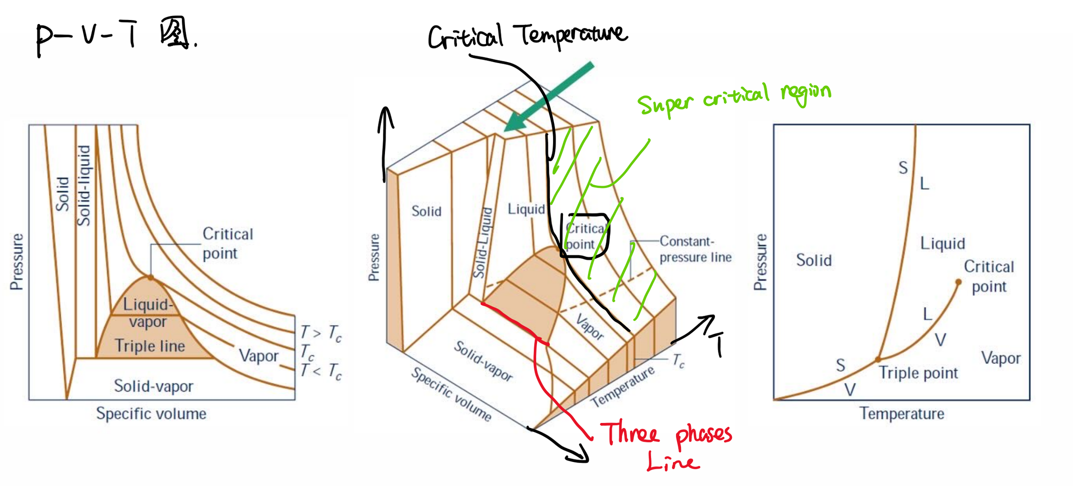


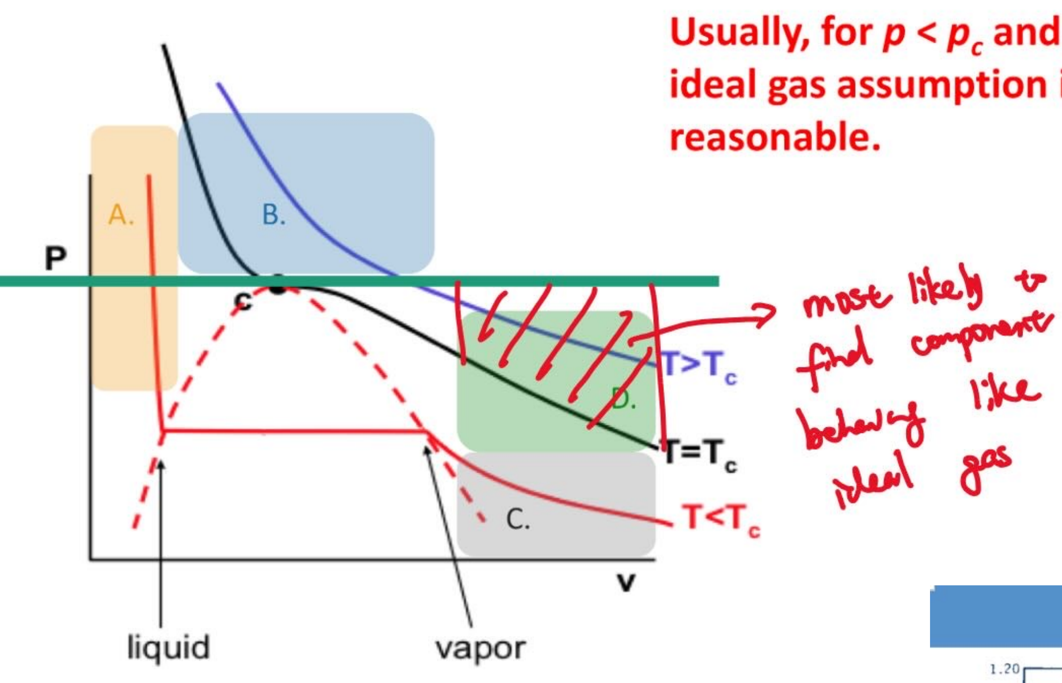
求解特定状态的 v

$$v = \frac{m_{liquid}}{m} v_f + \frac{m_{vapor}}{m} v_g$$
$$= (1-x) v_f + x v_g$$



p-v-T 图.





Usually, for $p < p_c$ and $T > T_c$, ideal gas assumption is reasonable.

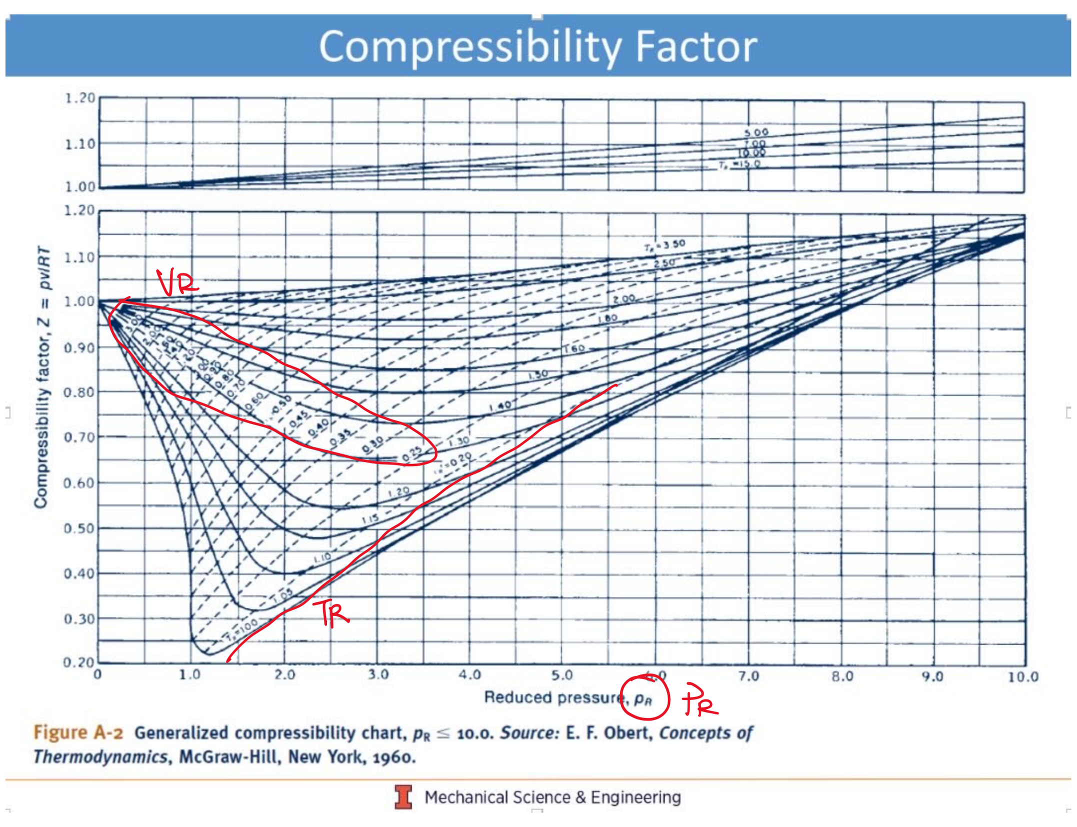


Figure A-2 Generalized compressibility chart, $p_R \le 10.0$. Source: E. F. Obert, Concepts of Thermodynamics, McGraw-Hill, New York, 1960.

表中的 $Z_c = \frac{P_c V_c}{R T_c}$ ⇒ 压缩系数，与 1 的比较代表 "idealness"

一般化 Ideal gas. $P_R = \frac{P}{P_c}$ $\quad V_R' = \frac{V}{V_c}$ $\quad T_R = \frac{T}{T_c}$ 确定 2 个，查表

找到 Z 后，有 $PV = ZRT$ $\quad \frac{8.314}{M} \times 1000$
specific volume.
Pseudo-reduced Specific Volume

☆ 查表用 P_R, V_R, T_R，计算用 P, V, T

☆. $V_R = \frac{V}{V_c}$ $\quad V_c = \frac{Z_c \cdot R T_c}{P_c}$, $\quad V = \frac{ZRT}{P}$

Hence $V_R = \frac{Z}{Z_c} \frac{T_R}{P_R}$ 因为此处假设 T_c, P_c, V_c 为理想气体
因此 $Z_c = 1$ (T_c, P_c 查表)

1st Law of Thermodynamics

1) For Macroscopic Control Volume

$$E_2 - E_1 = Q_{cv} - W_{cv} + m_i (h + \frac{V^2}{2} + gz)_i - m_e (h + \frac{V^2}{2} + gz)_e$$

☆ 简单来说，系统总体质量不变，视为 Steady-state，$\frac{dU}{dt} = 0$
而系统是否与外界交互则影响其 open / closed system.
Open system 由于会产生 flow work，因而计算采用 h.
Closed system 由于 $\Delta m = 0$ 且与外界不进行质量交换，因而使用 u.

2) For closed system

$$U_2 - U_1 = \Delta U = Q - W$$

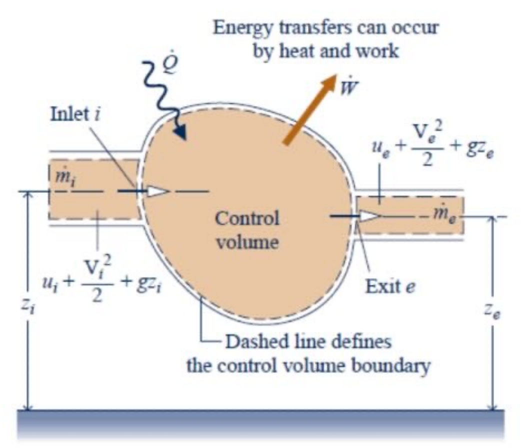
closed system $\xrightarrow{一定}$ steady state

3) For open system

$$\frac{dU}{dt} = \dot{Q} - \dot{W} + \sum \dot{m}_i h_i - \sum \dot{m}_e h_e$$

If steady state, then $\frac{dU}{dt} = 0$

☆ Steady-State Steady flow (SSSF)
$\sum \dot{m}(t) = 0 \quad \sum \dot{E}(t) = 0$

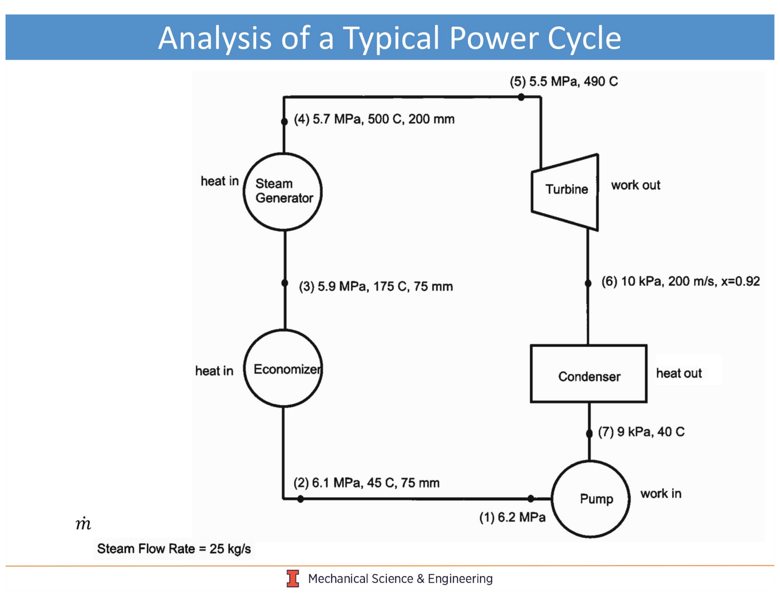


Mode of Energy transfer

1) Convective transport (对流运输) Unsteady-state + open system

$$\frac{dE_{cv}}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \sum \dot{m}_i (u + pe + ke + pv)_i - \sum \dot{m}_e (u + pe + ke + pv)_e$$

2)* Heat transfer
- Conduction $\dot{Q} = -kA\frac{dT}{dx}$
- Convection $\dot{Q} = hA(T_w - T_f)$
- Radiation $\dot{Q} = \varepsilon\sigma(T_H^4 - T_L^4)$



power cycle.

Turbine : 涡轮机 → 输出功 出来的气体是 Saturated-vapor

Pressure ↓ Velocity ↑ 对于蒸汽
☆ 由于进/出的温度状态的不同，
气体出 turbine 后由于温度升高而造成的体积膨胀
会影响其运动速度.

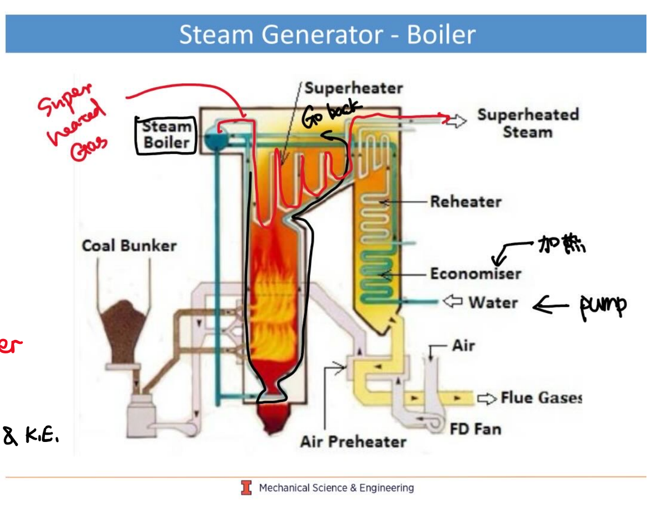
对于 Natural Gas turbine
velocity could decrease.

Assumptions for turbine analysis
1) Steady state 2) Adiabatic boundaries. ($\dot{Q} = 0$)
3) Equilibrium states at inlet & outlet ($\tau_{eq} \ll \tau_{pr}$)
4) Mass average velocity adequates for calculation.
5) No heat loss 6) ΔP.E could be negligible. ☆ΔK.E. 不忽略.

Steam Generator — Boiler

$\dot{W} = 0, \quad \frac{dE}{dt} = 0$

$\dot{E}(t) = \dot{Q} - \dot{W} + \dot{m}(h_3 - h_4 + ke_3 - ke_4)$
↑ Steady-state.



Condenser → A Heat exchanger
⇓
Steady-state + $\dot{W}$

Assumptions for Non-mixed heat exchanger
1) No work transfer 2) Steady state
3) Negligible heat loss 4) Neglect P.E. & K.E.
5) Lumped analysis is sufficient.
(集总分析)
6) Properties are defined at inlets (both) (属性在入口处定义)

Cycle.eff : $\eta = \frac{W_{on\ turbine}\ (-W_{pump})}{Q_{steam\ generator} + Q_{economizer}}$ 通常忽略此项

Throttling Process. (Joule-Thompson Effect) (节流过程)

Assumptions for T~P~
1) Negligible change in k.e. & p.e.
2) No shaft work (无轴功)
3) No heat transfer
4) SSSF or Steady-State

☆ Process
- Isothermal (等温) T → C
- Isobaric (等压) P → C
- Adiabatic (绝热) Q → 0
- Throttling (节流) h → C

☆ A quick review :

Throttle : $V_2 > V_1$, $z_2 = z_1$ 高度., $\dot{m}_2 = \dot{m}_1$, $h_2 = h_1$, $P_2 < P_1$, $v_2 > v_1$

Turbine : $V_2 > V_1$, $z_2 \approx z_1$, $\dot{m}_2 = \dot{m}_1$, $h_2 < h_1$, $p_2 < p_1$, $v_2 > v_1$

Compressor / Pump. V_2 ? 不能确定. $z_2 \approx z_1$, $\dot{m}_2 = \dot{m}_1$, $h_2 > h_1$, $P_2 > P_1$, $v_2 < v_1$