Introduction to Gas Power Cycles

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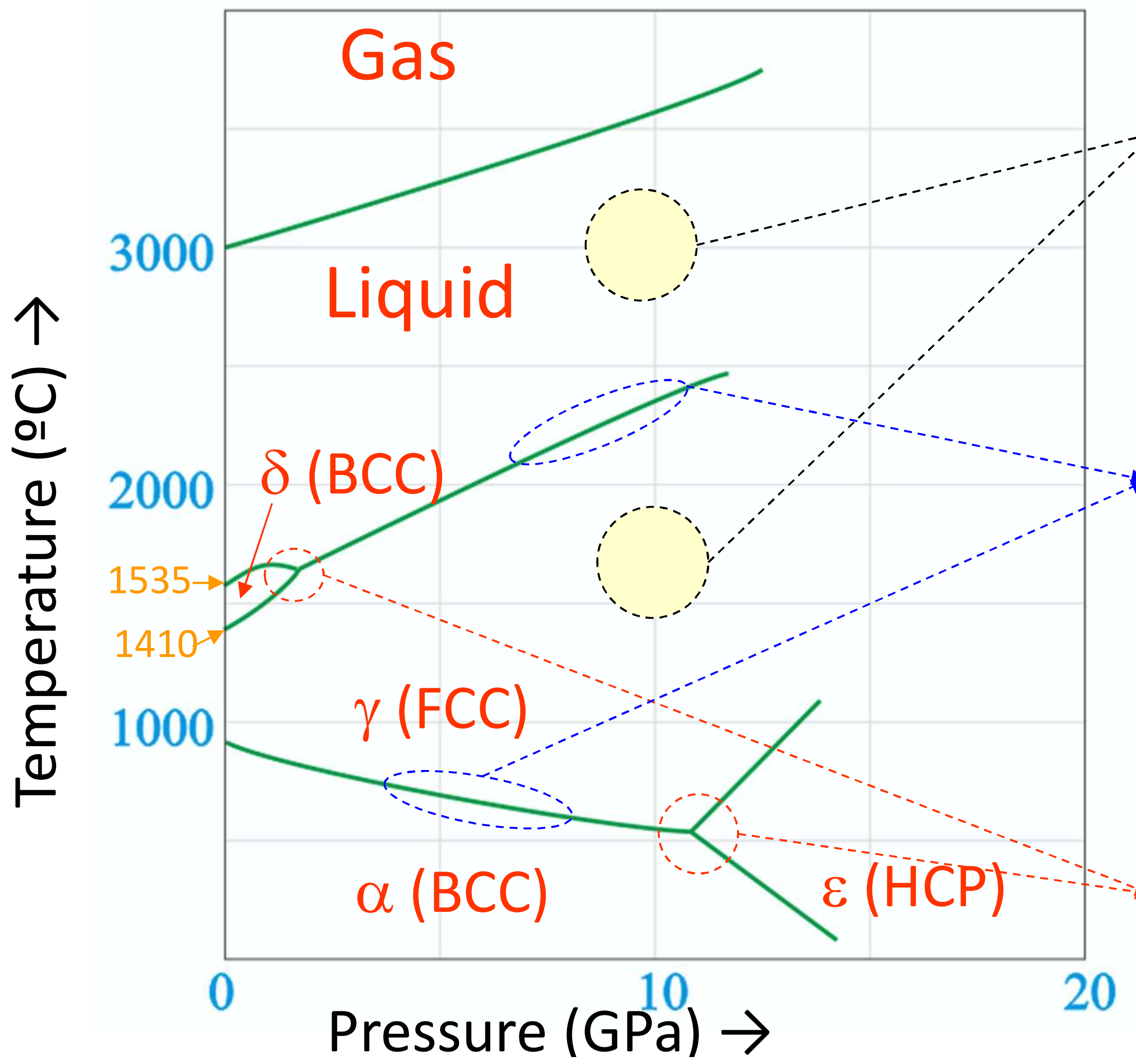
Previously: GIBBS PHASE RULE

- If α, β, γ,… are phases, then: $\mu_A(\alpha) = \mu_A(\beta) = \mu_A(\gamma)$….
- F = (Total number of variables) – (number of relations between variables)

  $= [P(C-1) + 2] - [C(P-1)] = C - P + 2$



Single phase *regions*

F = 1 – 1 + 2 = 2

⇒ T and P can both be varied while still being in the single phase region

Two phase coexistence *lines*

F = 1 – 2 + 2 = 1

⇒ we have only one independent variable (we can chose one of the two variables (T or P) and the other is 'automatically' fixed by the phase diagram)

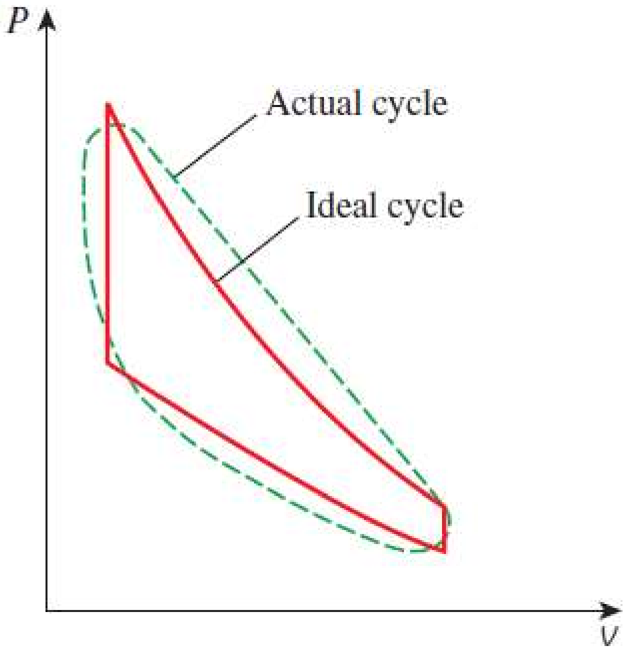
Triple *points*:

3 phase coexistence

F = 1 – 3 + 2 = 0

⇒ triple points are fixed points of a phase diagram (we cannot chose T or P)

Real Engines and Ideal cyles



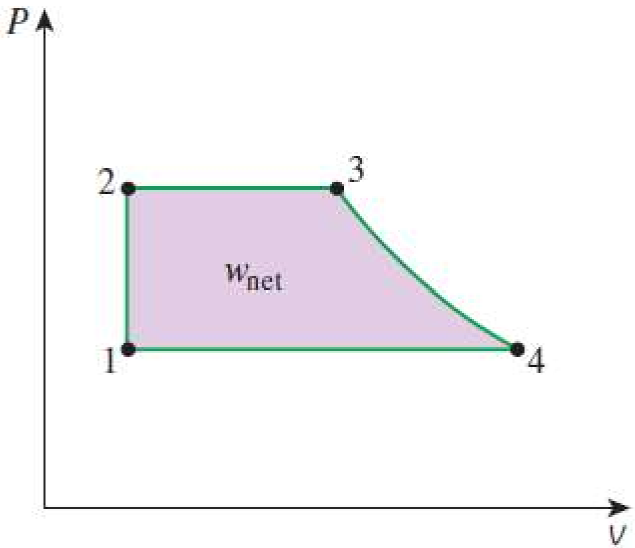
$$\eta_{th} = \frac{W_{net}}{Q_{in}} \quad \text{or} \quad \eta_{th} = \frac{w_{net}}{q_{in}}$$

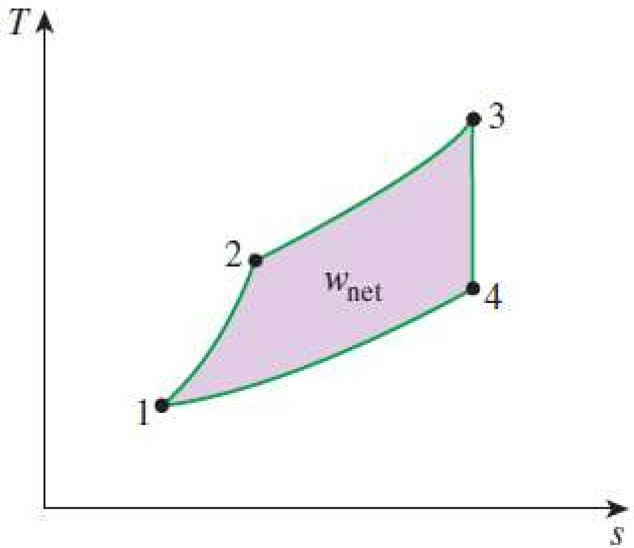
- Power generating *cycles* – Mechanical position/Working fluid
- Reversible operation

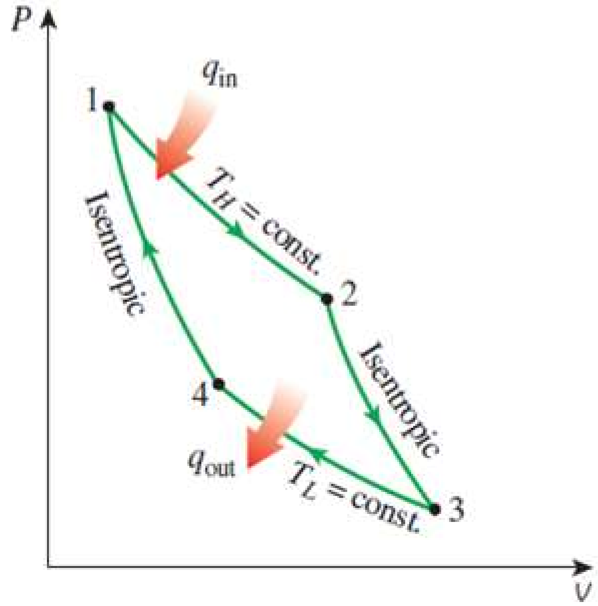
TD: Cengel & Boles

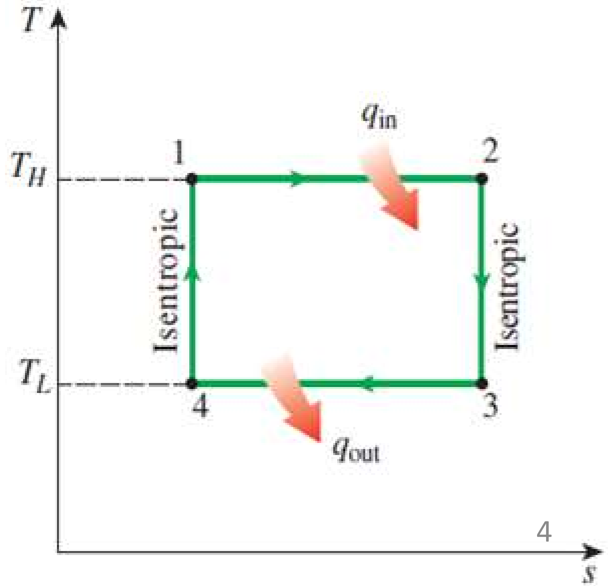
Real & Ideal cycles

- No friction; Quasi-equilibrium expansion & compression; No heat transfer losses; No KE & PE changes



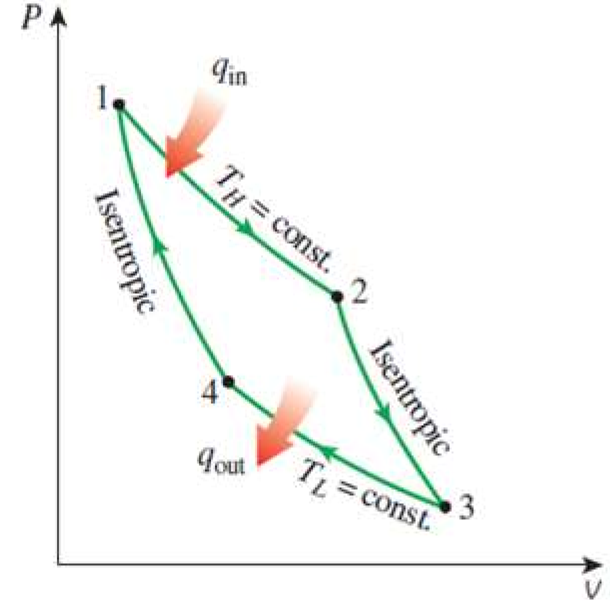


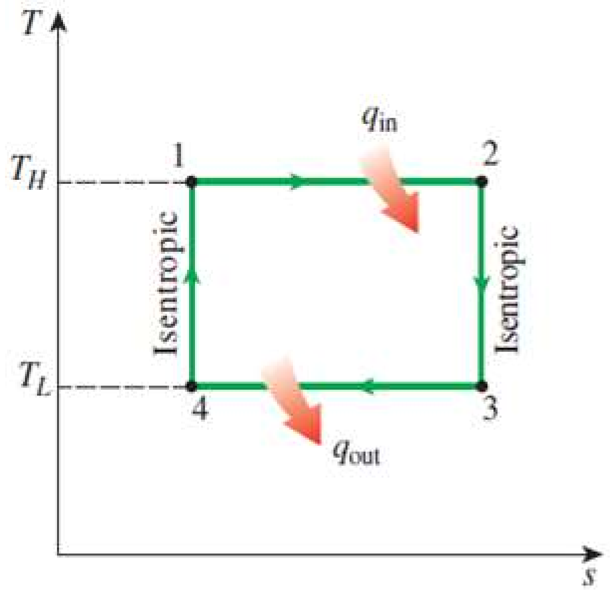


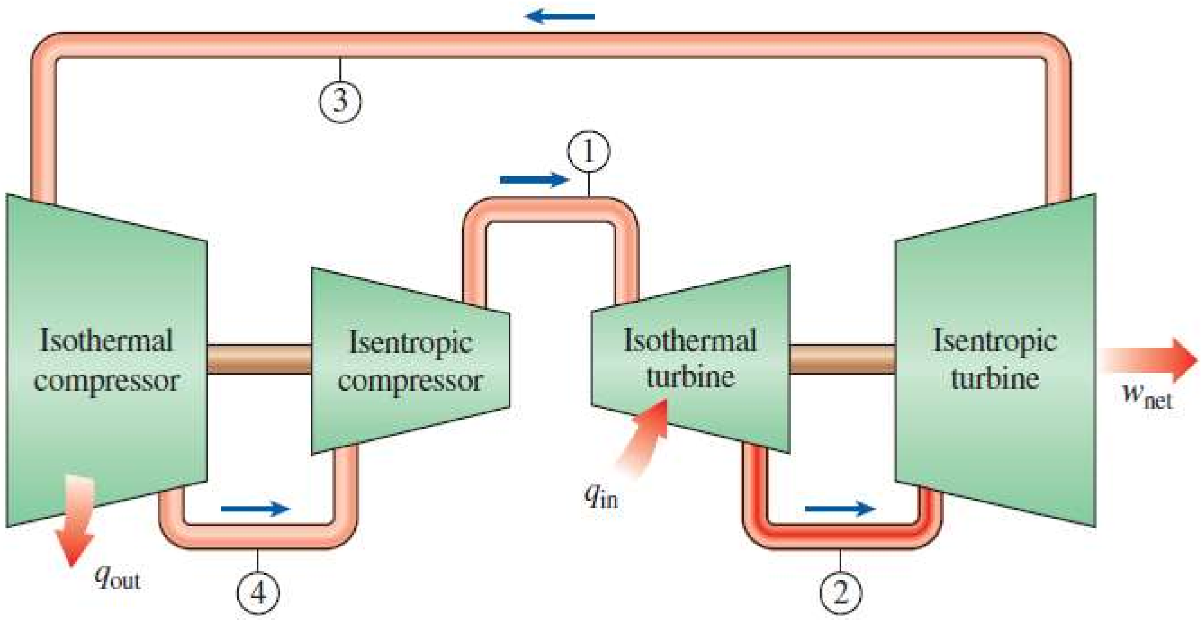


TD: Cengel & Boles

Realizing Steady Flow Carnot Cycle

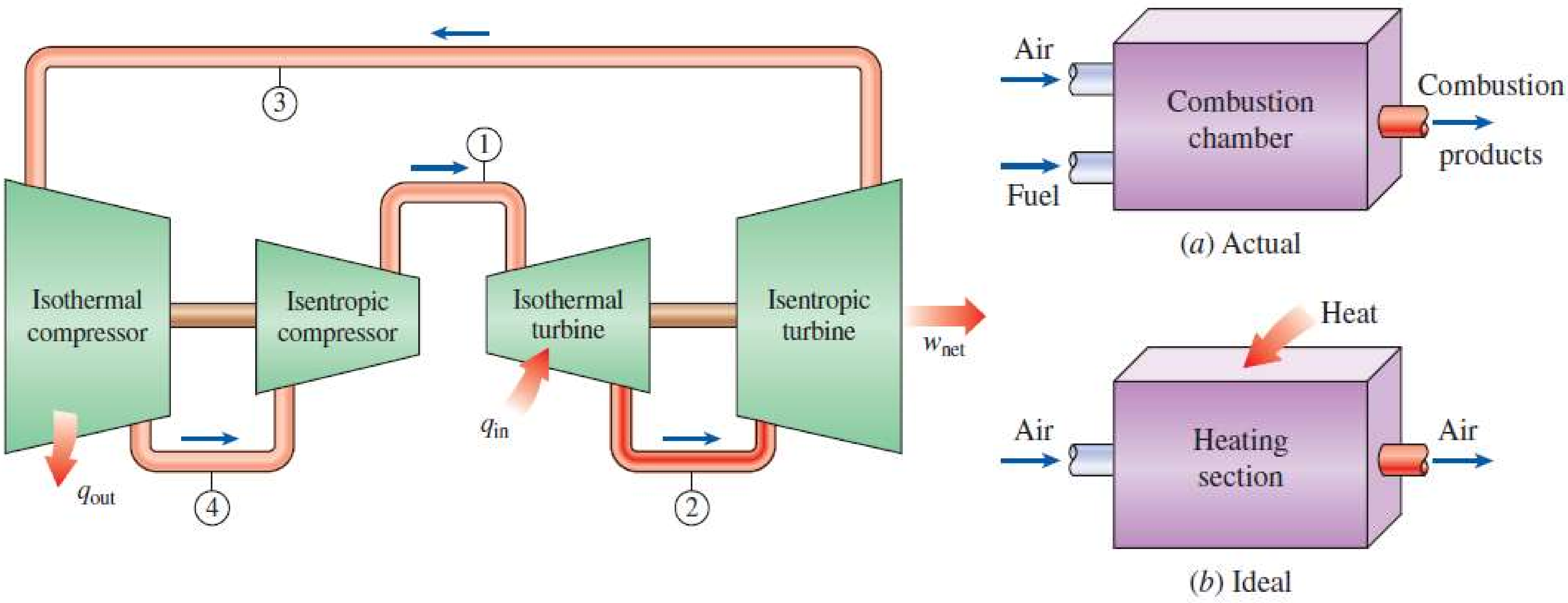






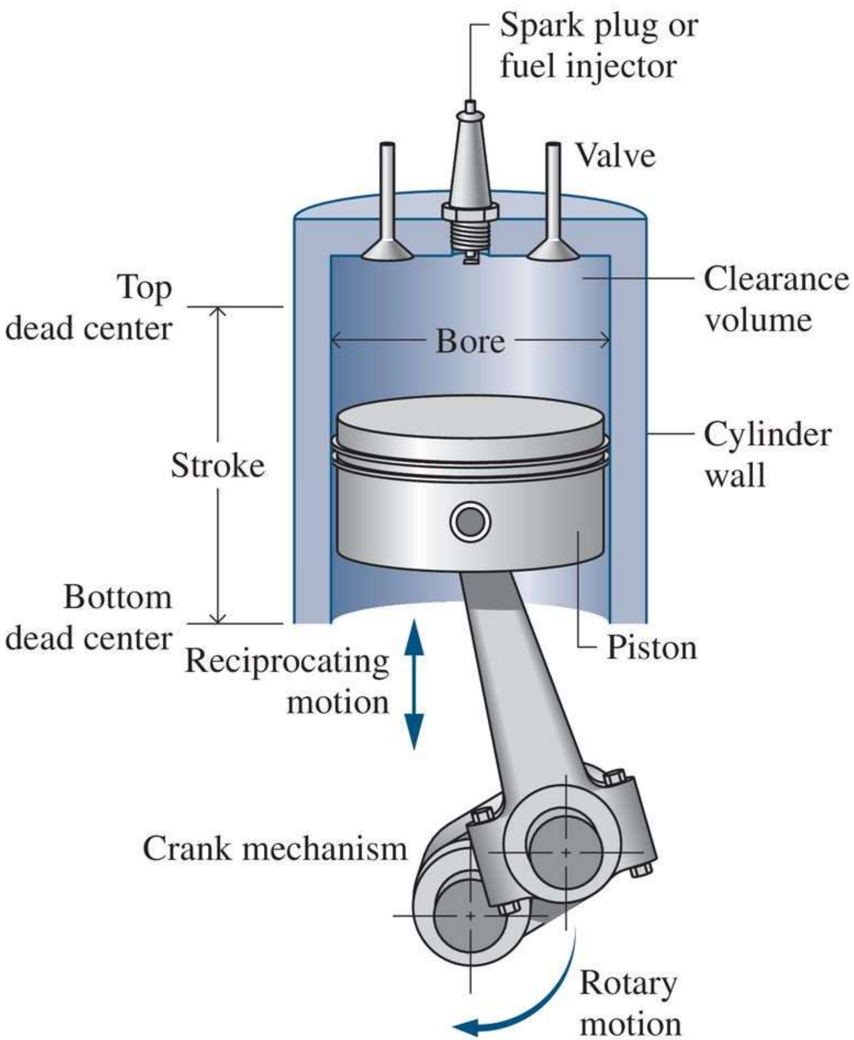
TD: Cengel & Boles

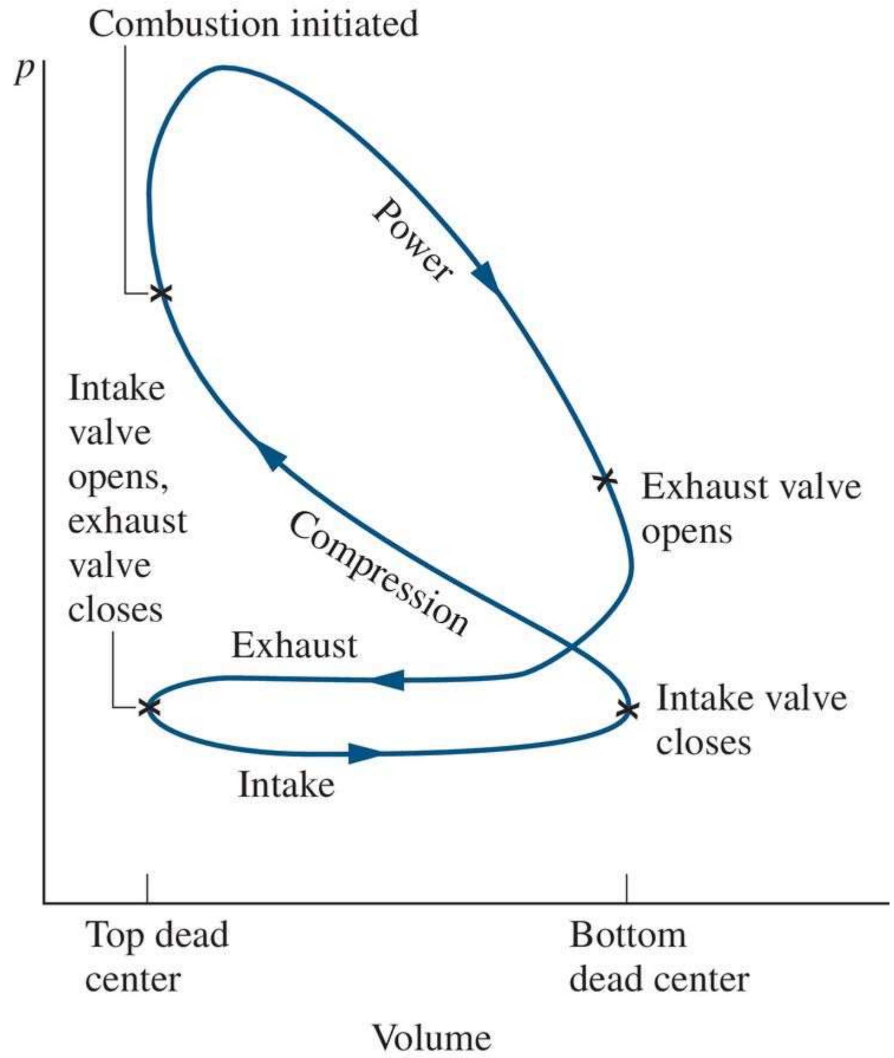
Internal & external combustion engine



TD: Cengel & Boles

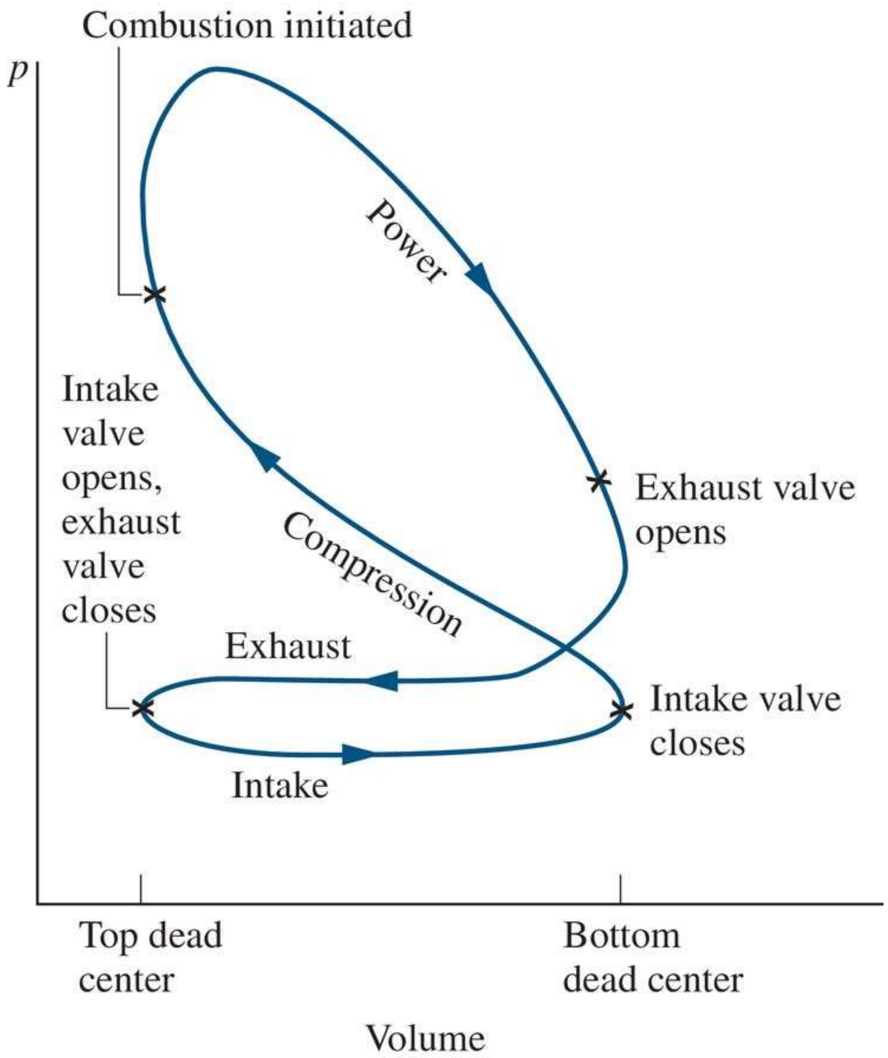
Reciprocating Engines



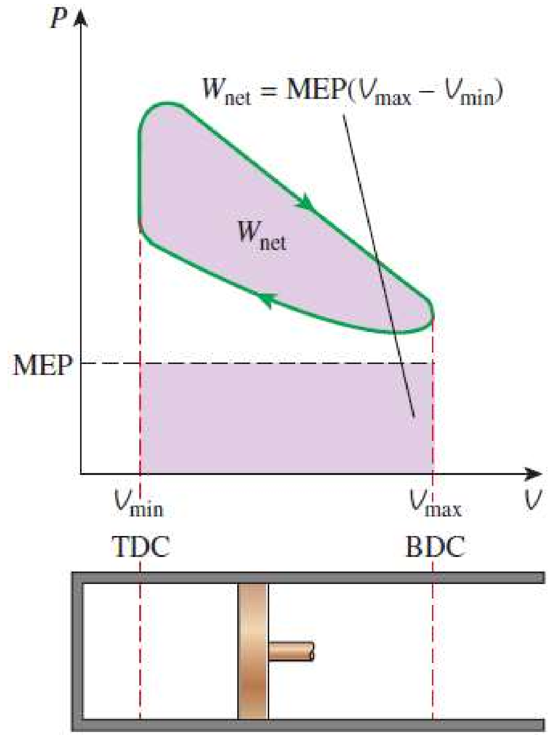


TD:Moran, Shapiro, Boettner & Bailey

Reciprocating Engines-MEP



$$\text{MEP} = \frac{W_{\text{net}}}{V_{\max} - V_{\min}} = \frac{w_{\text{net}}}{v_{\max} - v_{\min}} \quad \text{(kPa)}$$



$$W_{\text{net}} = \text{MEP} \times \text{Piston area} \times \text{Stroke} = \text{MEP} \times \text{Displacement volume}$$

TD: Cengel & Boles; Moran, Shapiro, Boettner & Bailey

Air-Standard Assumptions

- Fixed amount of circulating air is ideal with internal reversibility
- Heat generated externally via combustion added to the working fluid
- The exhaust process that makes the process cyclic is replaced by constant-volume heat transfer

2^{nd} TD law of engines

$$X_{\text{dest}} = T_0 S_{\text{gen}} = T_0(\Delta S_{\text{sys}} - S_{\text{in}} + S_{\text{out}})$$
$$= T_0\left[(S_2 - S_1)_{\text{sys}} - \frac{Q_{\text{in}}}{T_{b,\text{in}}} + \frac{Q_{\text{out}}}{T_{b,\text{out}}}\right] \qquad (\text{kJ})$$

Exergy destruction for a closed system

$$\dot{X}_{\text{dest}} = T_0 \dot{S}_{\text{gen}} = T_0(\dot{S}_{\text{out}} - \dot{S}_{\text{in}}) = T_0\left(\sum_{\text{out}} \dot{m}s - \sum_{\text{in}} \dot{m}s - \frac{\dot{Q}_{\text{in}}}{T_{b,\text{in}}} + \frac{\dot{Q}_{\text{out}}}{T_{b,\text{out}}}\right) \qquad (\text{kW})$$

For a steady-flow system

$$x_{\text{dest}} = T_0\left(\sum \frac{q_{\text{out}}}{T_{b,\text{out}}} - \sum \frac{q_{\text{in}}}{T_{b,\text{in}}}\right) \qquad (\text{kJ/kg})$$

Exergy destruction of a cycle

$$\phi = (u - u_0) - T_0(s - s_0) + P_0(v - v_0) + \frac{V^2}{2} + gz$$

Closed system exergy

$$\psi = (h - h_0) - T_0(s - s_0) + \frac{V^2}{2} + gz$$

Stream exergy

TD: Cengel & Boles

What's next?

- Otto-, Diesel-, Stirling- & Brayton-cycles