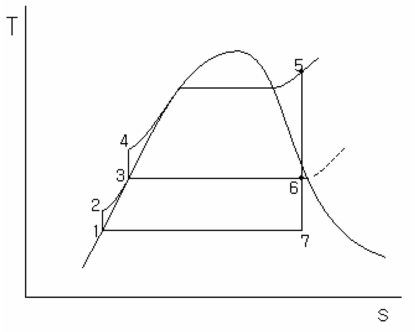
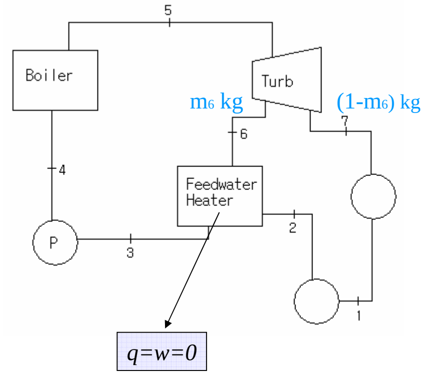
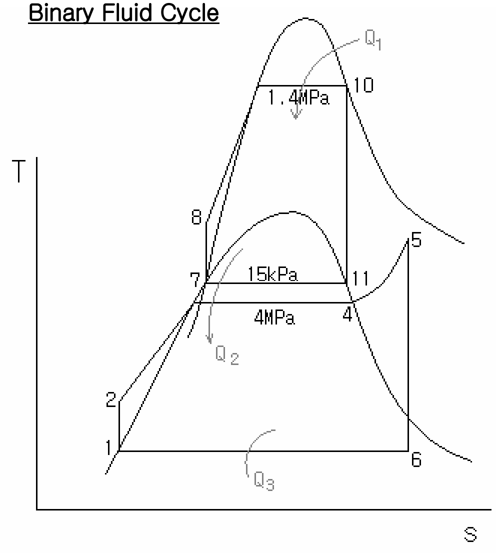
From last time...

- Regeneration Cycle
  uses feed-water heaters
  Efficiency is identical to that of Carnot cycle!





Binary Fluid Cycle

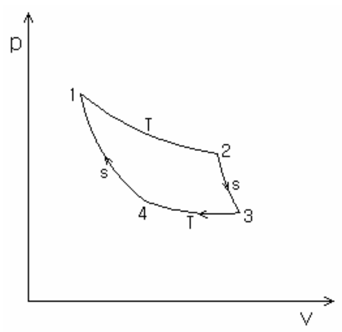


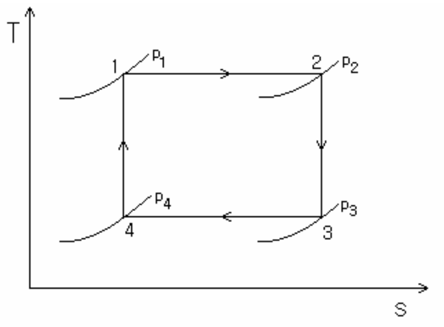
- 고온부에 적합한 유체(mercury)로 고온 사이클 형성.
- 저온부에 적합한 유체로 다른 사이클 형성.

Chapter 9 Air Standard Cycle

Steam cycle: 상변화 (L-G)
Air cycle: 단일상(G)

- Air-standard (공기표준) Carnot Cycle
  (ie Carnot cycle all at the superheated vapor zone)





Recall

$$\eta_{th} = 1 - \frac{T_L}{T_H} = 1 - \frac{T_3}{T_2} = 1 - \frac{T_4}{T_1}$$

Using isentropic relation for ideal gas

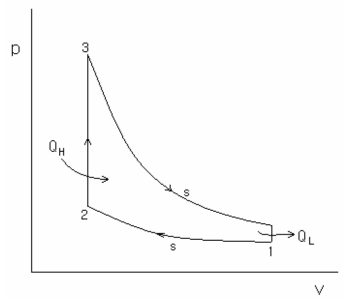
$$\frac{T_3}{T_2} = \left(\frac{p_2}{p_3}\right)^{\frac{1-\gamma}{\gamma}} = \left(\frac{p_1}{p_4}\right)^{\frac{1-\gamma}{\gamma}}$$

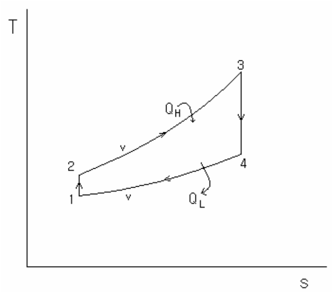
$$\frac{T_3}{T_2} = \left(\frac{V_3}{V_2}\right)^{\frac{1-\gamma}{1}} = \left(\frac{V_4}{V_1}\right)^{1-\gamma}$$

- Air-standard Otto Cycle

  Heat is transferred at constant $- v$.

  – ideal spark-ignition internal combustion engine.





1-2: Isentropic compression of air
2-3: Piston motion stops – heat is added.
(e.g. ignition of the fuel-air mixture)
3-4: Isentropic expansion
4-1: Rejection of heat from the air while piston motion is stopped.

$$\eta = 1 - \frac{Q_L}{Q_H} = 1 - \frac{mc_v(T_4 - T_1)}{mc_v(T_3 - T_2)} = 1 - \frac{T_1\left(\frac{T_4}{T_1} - 1\right)}{T_2\left(\frac{T_3}{T_2} - 1\right)}$$

Using isentropic process relations

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} \qquad \frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{\gamma-1}$$

$$v_1 = v_4 \qquad v_2 = v_3$$

$$\therefore \frac{T_2}{T_1} = \frac{T_3}{T_4} \quad or \quad \frac{T_3}{T_2} = \frac{T_4}{T_1}$$

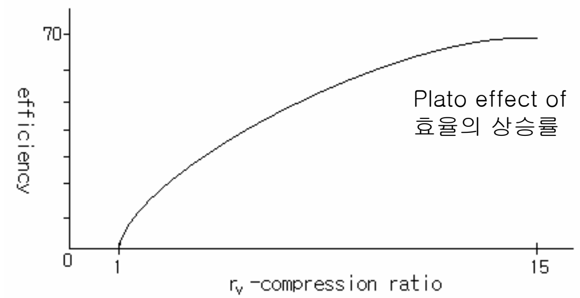
$$\eta_{th} = 1 - \frac{T_1}{T_2} = 1 - \frac{1}{\left(\frac{v_1}{v_2}\right)^{\gamma-1}}$$

$$= 1 - r_v^{1-\gamma}$$

$$= 1 - \frac{1}{r_v^{\gamma-1}}$$

where $r_v =$ compression ratio $= \frac{v_1}{v_2} = \frac{v_4}{v_3}$

$\eta \uparrow$ with $\uparrow$ compression ratio:



One can only $\uparrow r_v$ to a certain value to avoid explosion (엔진폭발).

→ 연료의 연소특성 및 제작문제로 제한이 있다.

→ spark knock- how to avoid?

Anti-knock gasoline →무연, add lead

- Diesel Cycle (as compared to Otto Cycle)

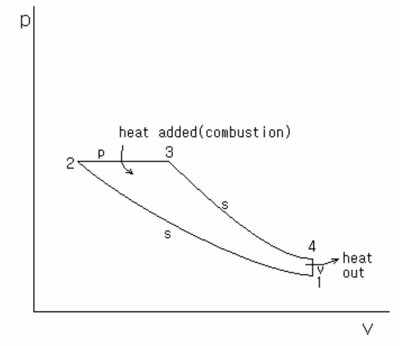
  Heat is added at constant $-p$ / rejects at constant $-v$

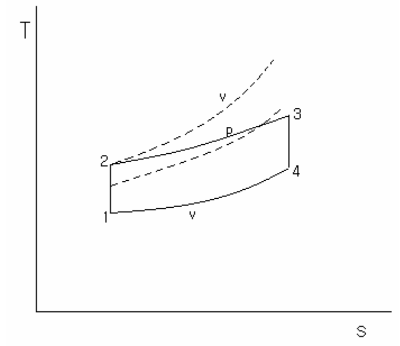
  - This is also called the compression ignition engine.
  - Injection and burning of the fuel in the actual engine.

$$\eta = 1 - \frac{Q_L}{Q_H} = 1 - \frac{c_v(T_4 - T_1)}{c_p(T_3 - T_2)} = 1 - \frac{T_1\left(T_4/T_1 - 1\right)}{RT_2\left(T_3/T_2 - 1\right)}$$

Note:

$$\delta Q = dE + pdV$$
$$= c_v dT + pdV \rightarrow use\, this\, if\ V - const.$$
$$\delta Q = dH - Vdp$$
$$= c_p dT - Vdp \rightarrow use\, if\ \ p - const.$$





Note isentropic compression (1→2) is greater than the expansion (3→4).

- Comparison of two cycles

$$\eta_{otto} > \eta_{Diesel}$$

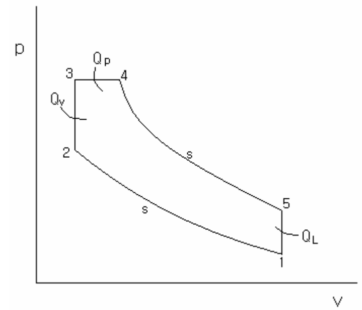
With some rearranging (Prove It!)

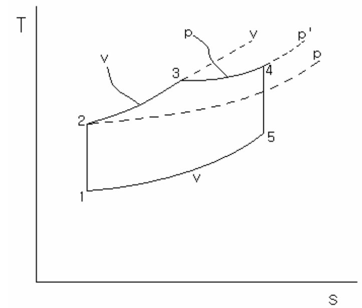
$$\eta = 1 - \underbrace{\frac{1}{r_v^{\gamma-1}}}_{Otto}\left\{\frac{r_c^{\gamma-1}}{\gamma\left(r_c - 1\right)}\right\}$$

Note:

불꽃점화 기관 (Otto cycle) 에서는 공기+연료를 압축.
압축점화 기관 (Diesel) 에서는 공기만을 압축한 후 연료를 분사.

- Mixed or Dual Cycle





$$Q_H = Q_v + Q_p$$
$$= mc_v(T_3 - T_2) + mc_p(T_4 - T_3)$$

$$Q_L = mc_v(T_5 - T_1)$$

$$\eta = 1 - \frac{c_v (T_5 - T_1)}{c_v (T_3 - T_2) + c_p (T_4 - T_3)}$$

$$r_v(\text{압축비}) = \frac{v_1}{v_2} \qquad r_c(\text{차단비}) = \frac{v_4}{v_3} \qquad r_p(\text{압력비}) = \frac{p_3}{p_2}$$

1-2: $T_2 = \left(\frac{v_1}{v_2}\right)^{k-1} T_1 = r_v^{\,k-1} T_1$

2-3: $T_3 = \left(\frac{p_3}{p_2}\right) T_2 = (r_p)(r_v^{\,k-1}) T_1$

3-4: $T_4 = \left(\frac{v_4}{v_3}\right) T_3 = r_c (r_p v_2^{\,k-1}) T_1$

4-5: $T_5 = \left(\frac{v_4}{v_5}\right)^{k-1} T_4 = \left(\frac{v_4}{v_3}\frac{v_3}{v_5}\right)^{k-1} T_4$

$$= \left(\frac{r_c}{r_v}\right)^{k-1} r_c r_p r_v^{\,k-1} T_1$$

$$= r_c^{\,k} r_p T_1$$

$$\eta_{th} = 1 - \frac{1}{r_v^{\,k-1}} \frac{r_p r_c^{\,k} - 1}{(r_p - 1) + k r_p (r_c - 1)}$$

열효율
Otto Cycle > Dual Cycle > Diesel Cycle