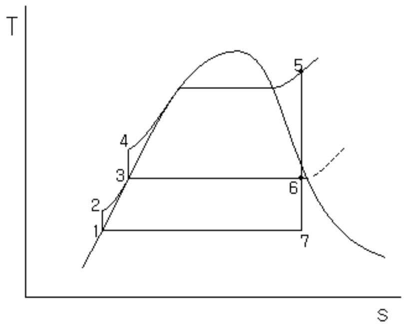
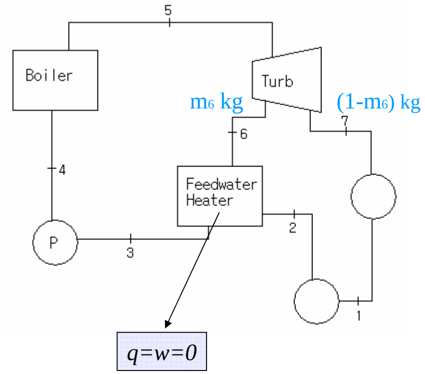
Chapter 8 continued...

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





- Turbine (5-6,7)
  Find x_6, using $s_5 = s_6$

$$6.7690 = 1.7766 + x_6 5.1193$$
$$and \ \ x_6 = 0.9752$$
$$h_6 = 604.7 + 0.9752(2133.8) = 2685.6$$

Find x_7, using $s_5 = s_7$

$$6.7690 = 0.6493 + x_7 7.5009$$
$$and \ \ x_7 = 0.8159$$
$$h_7 = 191.8 + 0.8159(2392.8) = 2144$$

Then 1st law:
$$w_t = h_5 - m_6 h_6 - (1 - m_6) h_7$$
$$= (h_5 - h_6) + (1 - m_6)(h_6 - h_7)$$

Fraction of 1 kg

And 2nd law: $s_5 = s_6 = s_7$

- Boiler

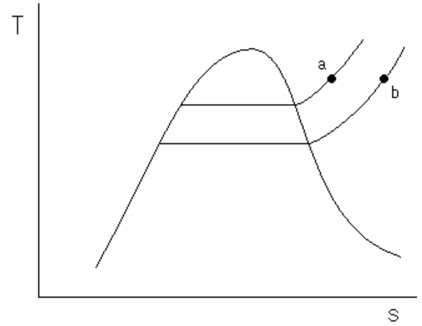
$$q_H = h_5 - h_4$$
$$= 3213.6 - 608.6 = 2605.0$$

$$\therefore \eta_{th} = \frac{w_{net}}{q_H} = \frac{975.7}{2605.0} = 37.5\%$$

That is, the q of feedwater heater is zero, thus
q_high is due to boiler only -> smaller denominator
-> greater efficiency

- Losses associated with actual cycle

- Piping Losses
  Friction effect
  Consider piping between
  Boiler and Turbine.

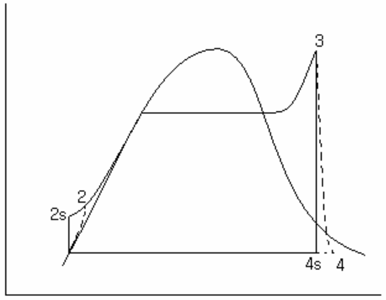


Turbine efficiency drops with a drop in pressure!
– Think about this!

Effect of losses between boiler and turbine →

State a – steam leaving the boiler
State b – steam entering turbine
Friction in the pipe causes an increase in entropy.

- Losses in turbine and pump



Pump efficiency drops with a rise in pressure!
– Think about this!

Effect of turbine and pump efficiencies on cycle performance.
– Due to irreversibility associated with the fluid flow.

- Condenser Losses

Cooling below the saturation temperature of the liquid leaving the condenser. (dh=Tds+ vdp와 constant p)

- Binary cycle (2 유체 사이클)

수은-수증기

We want to ↑ efficiency

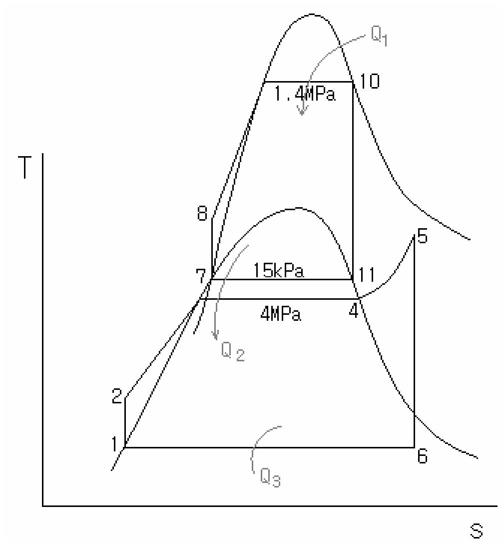
$$\eta = 1 - \frac{Q_L}{Q_H}$$

By $\uparrow Q_H, \downarrow Q_L$ or $T_H \uparrow, T_L \downarrow$

Consider fluid #2(mercury) whose $T_{cr} > 600°C$ while p_c is low.

So we combine 2 separate cycles.

Lower-T : steam
Higher-T: mercury



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

고온부의 응축, 냉각열을 저온부의 가열에 사용.

$$Cycle|_{mercury} \qquad \eta_A = \frac{W_A}{Q_H} = 1 - \frac{Q_2}{Q_1}$$

$$Cycle|_{steam} \qquad \eta_B = \frac{W_B}{Q_H} = 1 - \frac{Q_3}{Q_2}$$

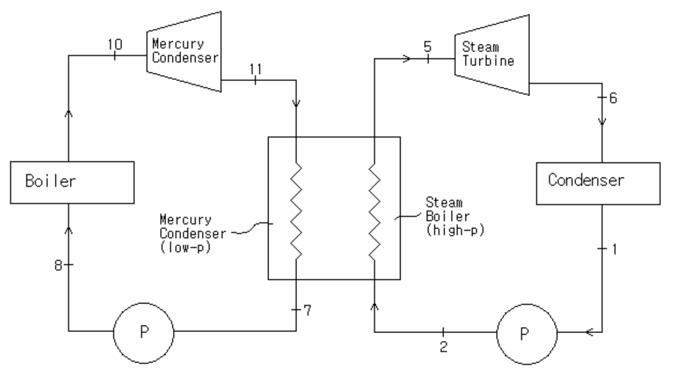
Combined cycle,

$$\eta_{AB} = 1 - \frac{Q_3}{Q_1}$$

$$1 - \eta_{AB} = (1 - \eta_A)(1 - \eta_B)$$

Typically $\eta_{bymanycycle} \sim 50\%$

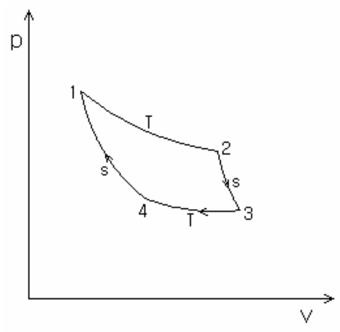
Very good except Mercury is way too toxic!!

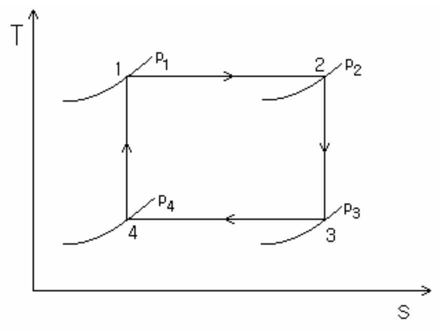


Chapter 9 Air Standard Cycle

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

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





Recall

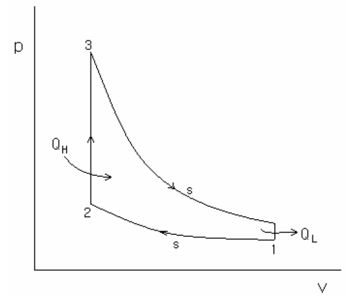
$$\eta_{th} = 1 - \frac{T_L}{T_H} = 1 - \frac{T_3}{T_2} = 1 - \frac{T_4}{T_1}$$

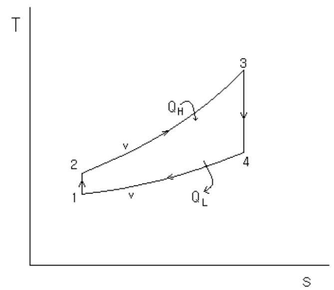
Using isentropic relation for ideal gas

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

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

- 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

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

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

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

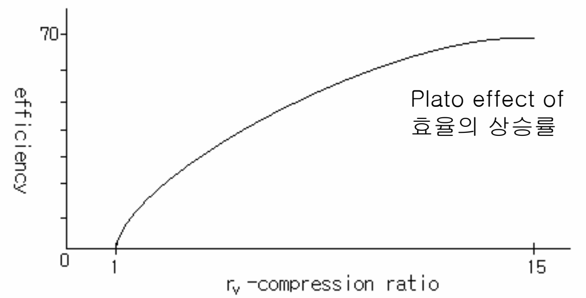
$$\eta_{th} = 1 - \frac{T_1}{T_2} = 1 - \frac{1}{\left(\frac{v_1}{v_2}\right)^{k-1}}$$

$$= 1 - r_v^{\,1-k}$$

$$= 1 - \frac{1}{r_v^{\,k-1}}$$

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