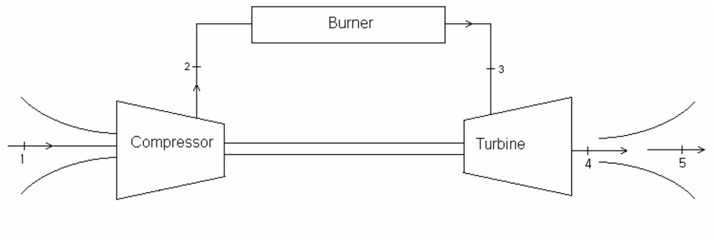
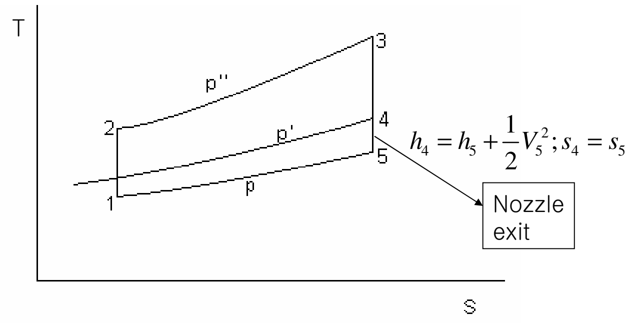
- Air-Standard Cycle for Jet Propulsion



3-4 Turbine
4-5 Nozzle



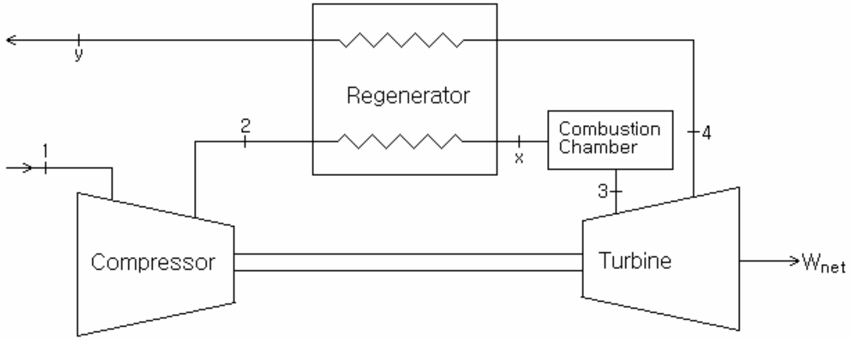
$$h_4 = h_5 + \frac{1}{2}V_5^2 ; s_4 = s_5$$

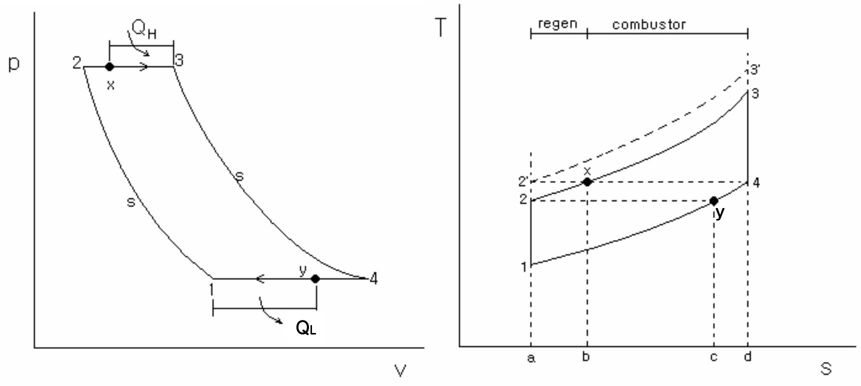
p'' > p' > p

The gases are expanded in the turbine to a pressure for which the turbine work is just equal to the compressor work.

Since the gases leave at a high velocity, the change in momentum that the gases undergo gives a thrust to the aircraft in which the engine is installed.

- Gas turbine with regenerator





Regenerator ≡ counter flow heat exchanger

$$T_x = T_4$$

x – 3 – d – b – x : the heat transferred
y – c – a – 1 – y : heat rejected

Note:
For Ideal gas

$$T\,ds = de + p\,dv \qquad T\,ds = dh - v\,dp$$
$$= c_v\,dT + p\,dv \qquad = c_p(T_2 - T_1) - v\,dp$$

Isentropic;

$$T\,ds = q$$

$$\left.\begin{aligned} \eta &= \frac{w_{net}}{q_H} = \frac{w_t - w_c}{q_H} \\ q_H &= c_p(T_3 - T_x) \\ w_t &= c_p(T_3 - T_4) \end{aligned}\right\}$$

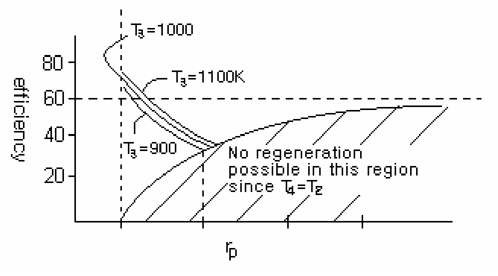
Since $T_x = T_4$

So $q_H = w_t$

$$\eta = \frac{q_H - w_c}{q_H} = 1 - \frac{w_c}{q_H}$$
$$= 1 - \frac{c_p(T_2 - T_1)}{c_p(T_3 - T_4)}$$
$$= 1 - \underbrace{\frac{T_1}{T_3}}_{This\,is\,new}\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

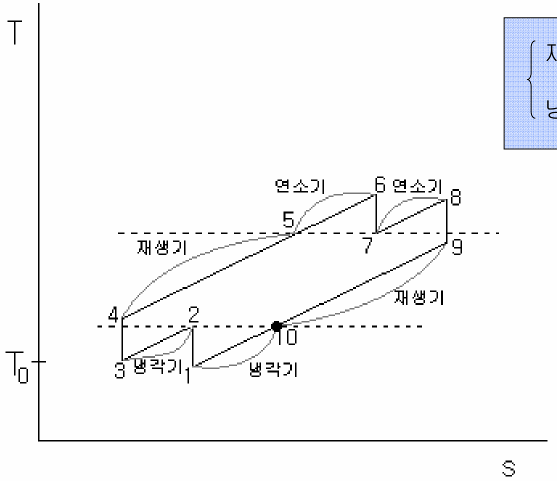
$\therefore \eta$ – depends on 2 things

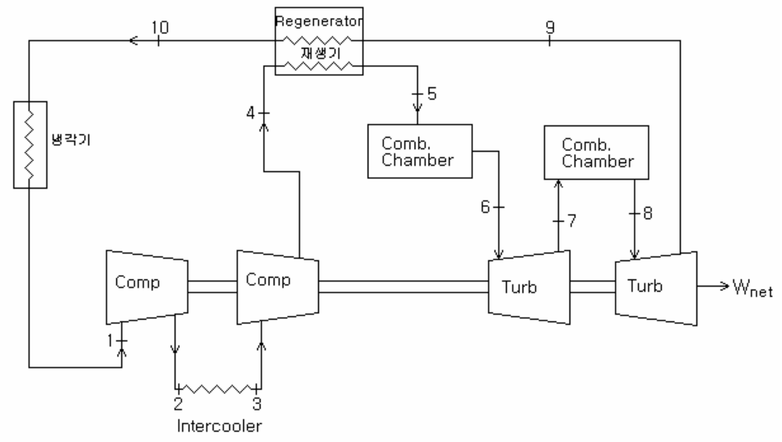
1. pressure ratio
2. T – max, min



- Ideal gas-turbine cycle using inter-cooling and regenerator

재생기
냉각기





중간
냉각기

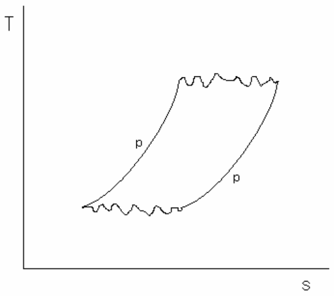
Recall $\eta_{ericsson+재생기} = \eta_{carnot}$ Use p194 for explanation!

가급적 터어빈에서의 팽창은 온도가 높은 쪽에서 이루어지도록 하여 터어빈 일을 크게 할 수 있고,

압축기는 가급적 낮은 온도에서 사용하여야 압축일이 작아짐을 알 수 있다.

-> 효율은 증가시킴!

If large number of multi stage is used, we recover to Ericsson Cycle!



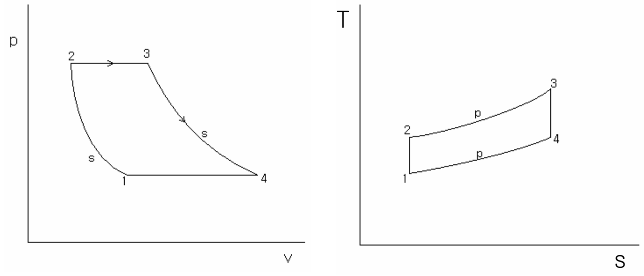
≈ Ericsson Cycle

- Example

In an air-standard Brayton cycle, the air enters the compression at 0.1Mpa, 15°C. The pressure leaving the compression is 1.0Mpa, and the maximum temperature in the cycle is 1100°C. Determine

a. The pressure and temperature at each point in the cycle.

b. The compression work. Turbine work, and cycle efficiency.



$p_1 = 0.1MPa$, $T_1 = 15°C$

$p_2 = 1.0MPa = p_3$, $T_3 = 1100°C$

Compressor:

1st Law: $w_c = h_2 - h_1$

2nd Law: $s_2 = s_1$

So
$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \qquad \gamma = 1.4$$
$$= 10^{0.286} = 1.932$$

$$T_2 = 556.8K$$

Or

$$w_c = h_2 - h_1 = c_p(T_2 - T_1)$$
$$= (1.0035)(556.8 - 288) = 269.5kJ/kg$$

Turbine:

1st Law: $w_t = h_3 - h_4$

2nd Law: $s_3 = s_4$

So $\frac{T_3}{T_4} = \left(\frac{p_3}{p_4}\right)^{\frac{\gamma-1}{\lambda}} = 10^{0.286} = 1.932,\ T_4 = 710.8K$

$$w_t = h_3 - h_4 = c_p(T_3 - T_4)$$
$$= (1.0035)(1373 - 710.8) = 664.7kJ/kg$$

$$w_{net} = w_t - w_c = 664.7 - 269.5 = 395.2kJ/kg$$

High-T Heat Exchanger

1st Law: $q_H = h_3 - h_2 = c_p(T_3 - T_2)$

$$q_H = c_p(T_3 - T_2) = 1.0035(1373.2 - 556.8)$$
$$= 819.3kJ/kg$$

Low-T Heat Exchanger

1st Law: $q_L = h_4 - h_1 = c_p(T_4 - T_1)$

$$q_L = c_p(T_4 - T_1) = 1.0035(710.8 - 288)$$
$$= 424.1kJ/kg$$

Therefore,

$$\eta_{th} = \frac{w_{net}}{q_H} = \frac{395.2}{819.3} = 48.2\%$$

Recall previously we found the efficiency of this cycle as
(Check it!)

$$\eta = 1 - \frac{1}{\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}}} = 1 - \frac{1}{10^{0.286}} = 48.2\%$$

The SAME !