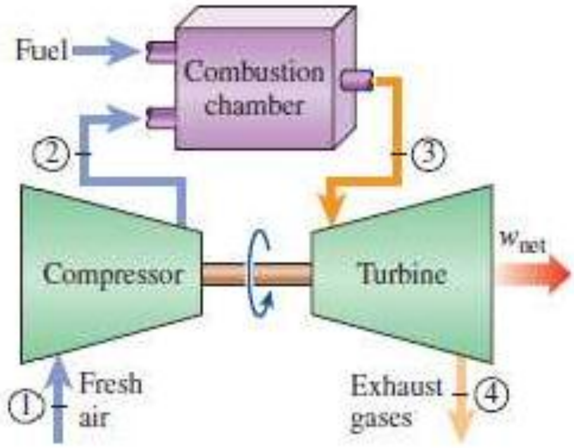
2.4 BRAYTON CYCLE ANALYSIS & OPTIMIZATION

The Brayton cycle is the ideal cycle for gas-turbine engines. Today, it is used for gas tubines in which both the compression and expansion processes are implemented. There are two different types of the Brayton cycle; the open gas turbine cycle and the closed gas turbine cycle respectively.

The difference between these two cycles is that during the open gas turbine cycle, a combustion process takes place, and exhaust gases are thrown out, in other words the exhaust gases cannot be recirculated, while in the other cycle (the closed gas turbine cycle), the combustion process is replaced by a heat-addition process, the exhaust gases are also utilized so as to increase the temperature of the air which enters the compressor.

In Figure 1, the open gas turbine cycle is shown. First, fresh air at ambient condition is taken into the compressor, and here the air temperature and pressure are raised, resulting of the compression process. Second, the high-pressure air draws into the combustion chamber, and it mixes with the fuel.

Here, the combustion process occurs at constant temperature. Third, the resulting high-temperature gases enter the turbine to generate power. In this operation, the hot gases are expand to the atmospheric pressure. Finally, the exhaust gases leaving the turbine are discharged.

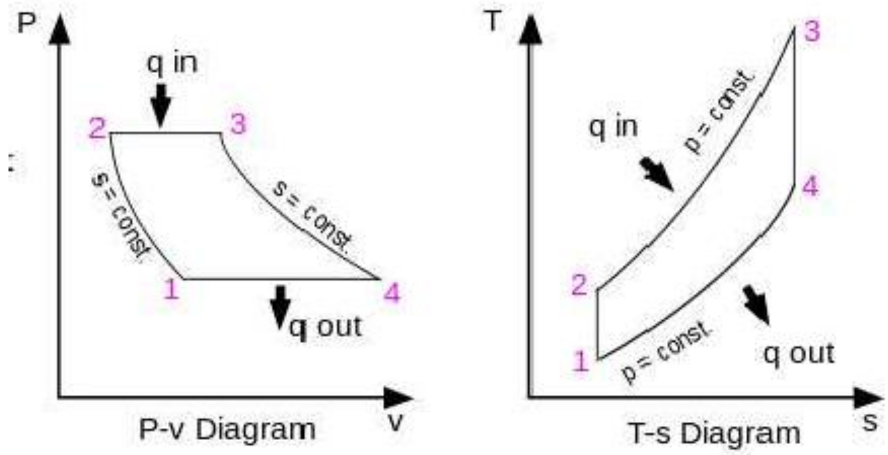


In the closed-gas turbine cycle, although the compression and expansion process have in common, combustion chamber is replaced by a heat exchanger in which increases the compressed air temperature. As given in Figure 2, ideal Brayton cycle is actually a closed-gas turbine cycle, and the steps of the Brayton cycle are like following;

1–2 Isentropic compression in the compressor

2–3 Constant pressure heat addition

3–4 Isentropic expansion in the turbine 4–1 Constant pressure heat rejection



$$\eta_{th} = \frac{\text{Heat added - Heat rejected}}{\text{Heat added}}$$

$$\eta_{th} = \frac{mC_p(T_3 - T_2) - mC_p(T_4 - T_1)}{mC_p(T_3 - T_2)} = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

For isentropic processes, we have,

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \text{ and } \frac{T_3}{T_4} = \left(\frac{p_3}{p_4}\right)^{\frac{\gamma-1}{\gamma}}$$

But, $p_2 = p_3$ and $p_1 = p_4$, thus,

$$\frac{T_2}{T_1} = \frac{T_3}{T_4}$$

and we can write,

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

$$\frac{T_4}{T_3} = \frac{T_1}{T_2} = \frac{v_2}{v_1} = \frac{1}{r^{\gamma-1}}$$

$$\frac{1}{r^{\gamma-1}} = \left(\frac{v_2}{v_1}\right)^{\gamma-1} \left\{\left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}}\right\}^{\gamma-1} = (r_p)^{\frac{\gamma-1}{\gamma}}$$

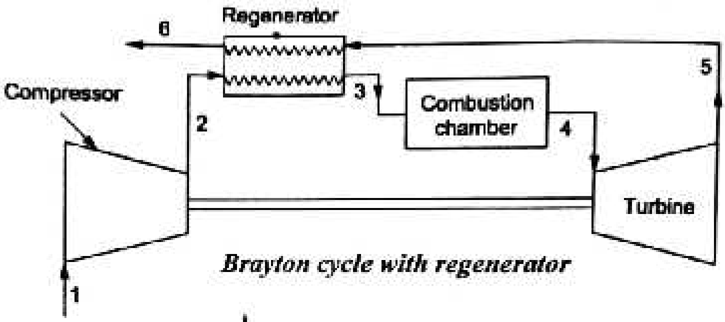
$$\eta_{th} = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

IMPROVISATION OF BRAYTON CYCLE

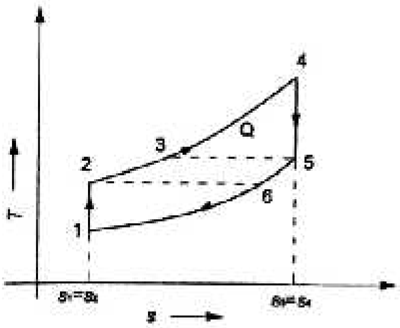
The efficiency of gas turbine power plant can be improved in four ways such as

1. Brayton cycle with regeneration
2. Brayton cycle with intercooling
3. Brayton cycle with reheating
4. Brayton cycle with combined regeneration, intercooling and reheating

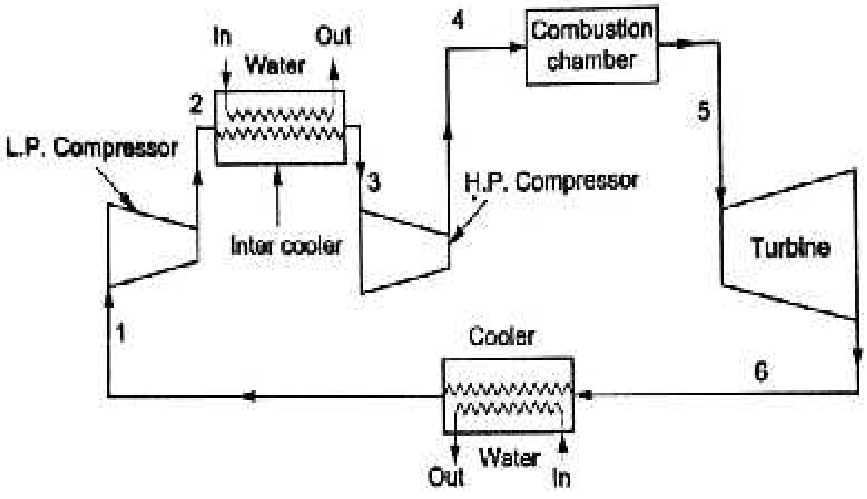
1. Brayton cycle with regeneration



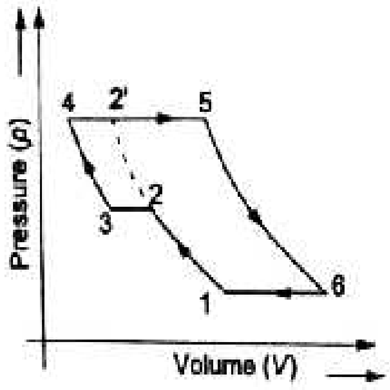
Brayton cycle with regenerator



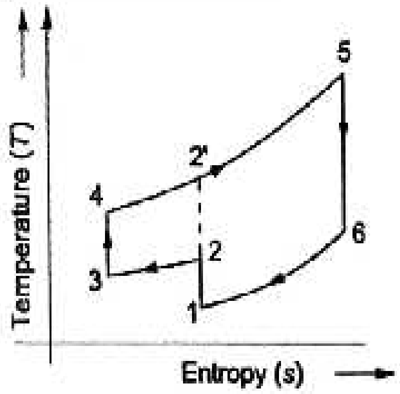
2. <u>Brayton cycle with intercooling</u>



Brayton cycle with intercooler

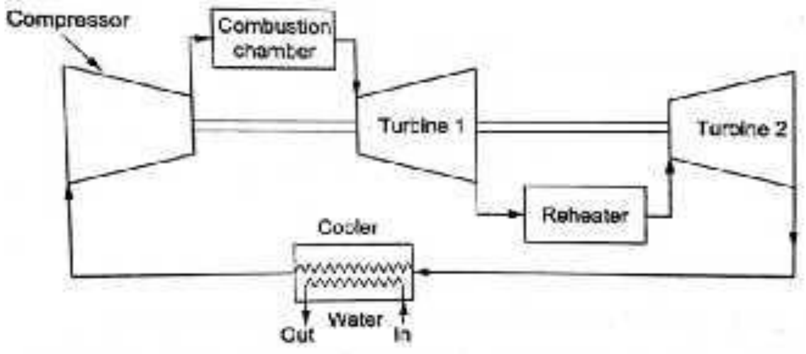


p-V diagram

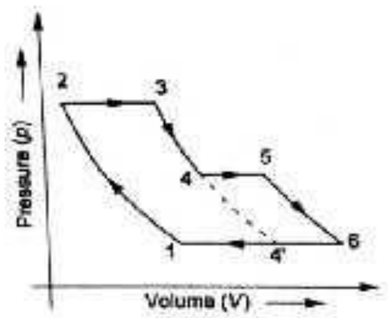


T-s diagram

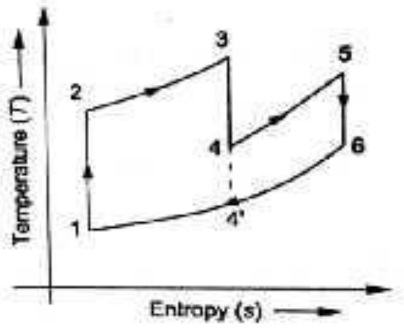
3. Brayton cycle with reheating



Brayton cycle with reheater

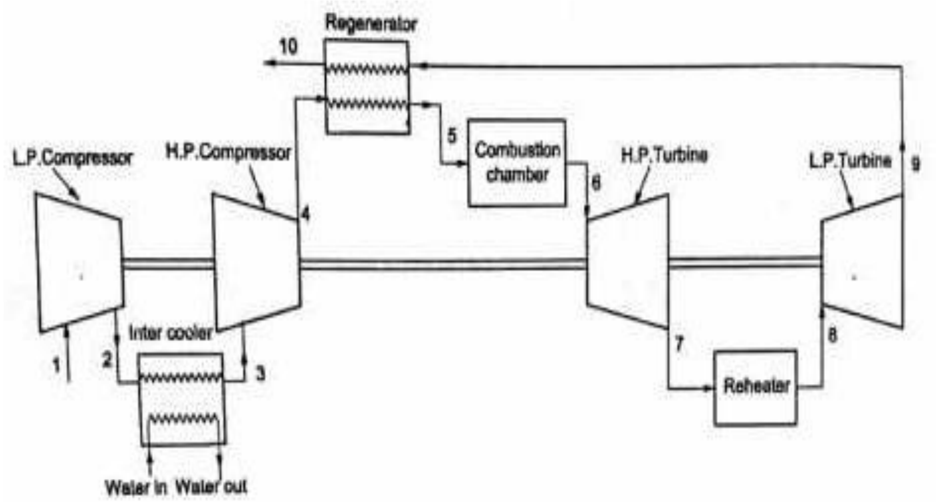


p-V diagram



T-s diagram

4. <u>Brayton cycle with combined regeneration, intercooling and reheating</u>



Brayton cycle with intercooler, reheater and regenerator