Gas Turbine Power Plant

Gas Turbine Plant

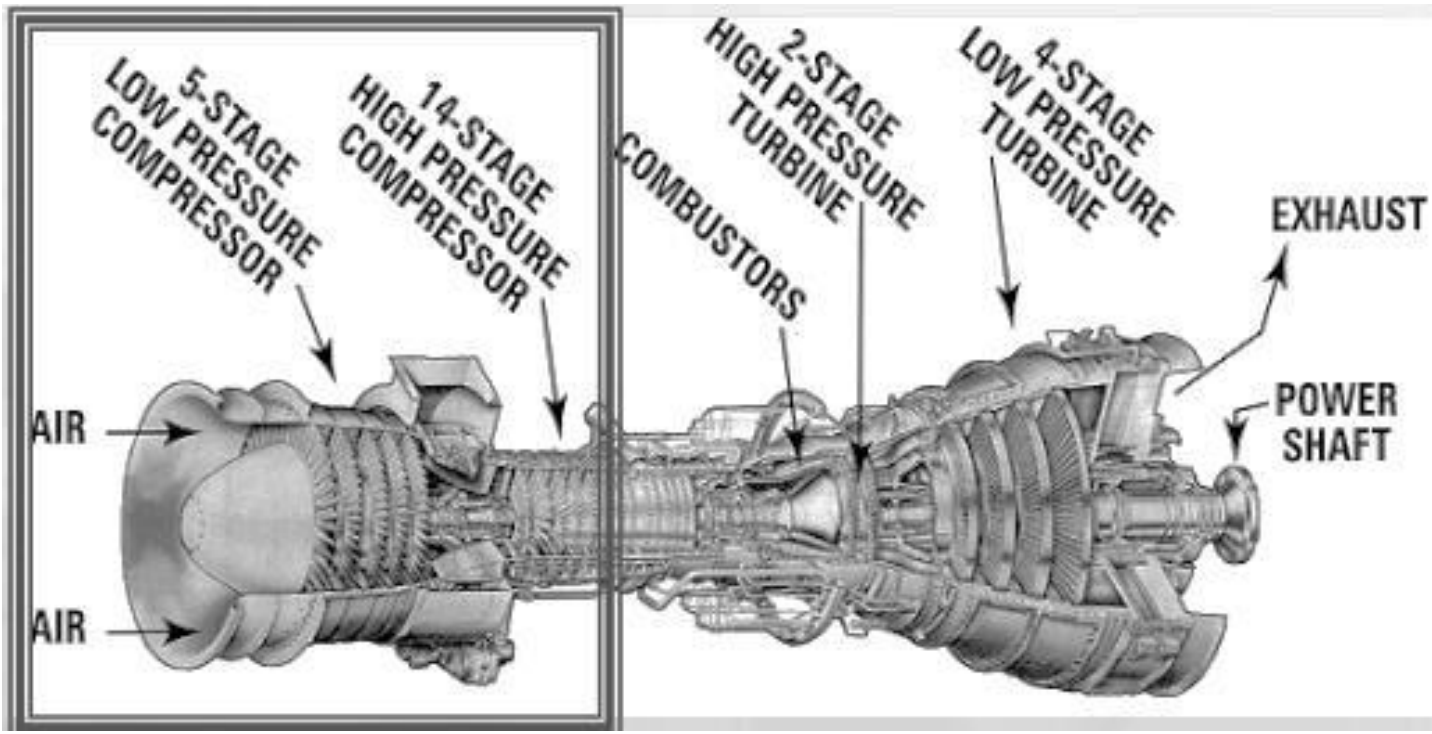
Gas turbine engines derive their power from burning fuel in a combustion chamber and using the fast flowing combustion gases to drive a turbine in much the same way as the high pressure steam drives the steam turbine.

A simple gas turbine is comprised of three main sections a compressor, a combustor and a power turbine.

The gas turbine operates on the principle of the Brayton cycle, where compressed air is mixed with fuel, and burned under constant pressure conditions.

The resulting gas is allowed to expand through a turbine to perform work.

Gas turbines are widely used in Aircraft propulsion system, Electric power generation, Marine vehicle propulsion


5-STAGE
LOW PRESSURE
COMPRESSOR
14-STAGE
HIGH PRESSURE
COMPRESSOR
COMBUSTORS
2-STAGE
HIGH PRESSURE
TURBINE
4-STAGE
LOW PRESSURE
TURBINE
EXHAUST
AIR
AIR
POWER
SHAFT

1. Compressor

The compressor sucks in air form the atmosphere and compresses it to pressures in the range of 15 to 20 bars. The compressor consists of a number of rows of blades mounted on a shaft. The shaft is connected and rotates along with the main gas turbine.

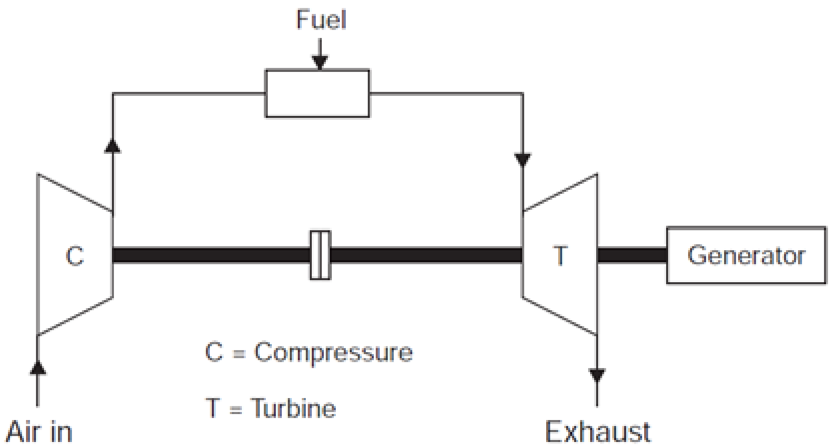
2. Combustor

This is an annular chamber where the fuel burns and is similar to the furnace in a boiler. The hot gases in the range of 1400 to 1500 ℃ leave the chamber with high energy levels. The chamber and the subsequent sections are made of special alloys and designs that can withstand this high temperature

3. Turbine

The turbine does the main work of energy conversion. The turbine portion also consists of rows of blades fixed to the shaft. The kinetic energy of the hot gases impacting on the blades rotates the blades and the shaft. The gas temperature leaving the Turbine is in the range of 500 to 550 ℃. The gas turbine shaft connects to the generator to produce electric power.

Gas Turbine Plant

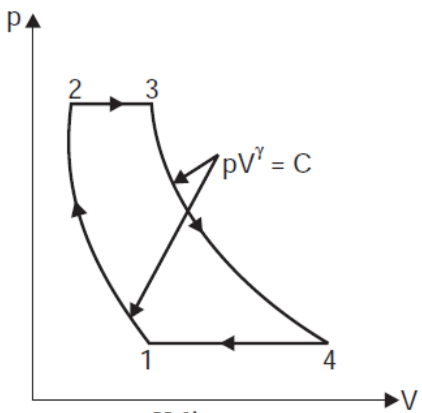


A simple gas turbine plant consists of the following :

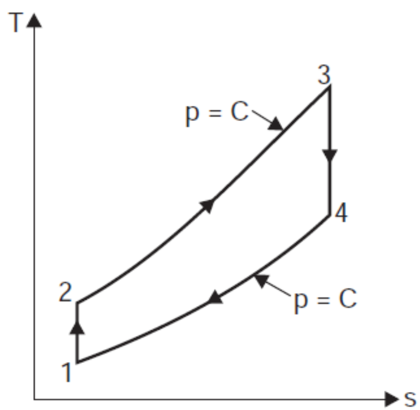
1. *Turbine*.
2. *A compressor* mounted on the same shaft or coupled to the turbine.
3. *The combustor*.
4. *Auxiliaries* such as starting device, auxiliary lubrication pump, fuel system, oil system and the duct system etc.

GAS TURBINE CYCLE—BRAYTON CYCLE

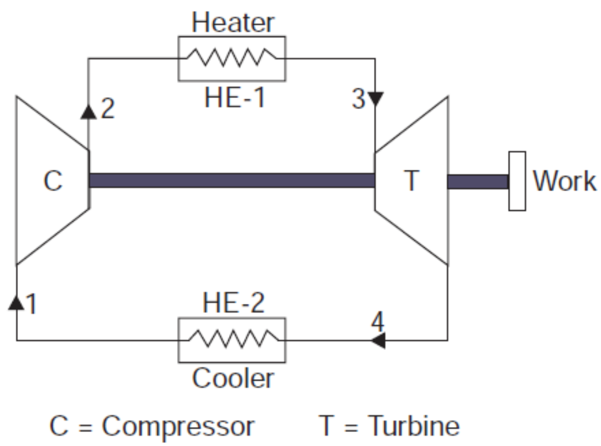
Brayton cycle is *a constant pressure cycle for a perfect gas*. It is also called **Joule cycle.**



p-V diagram



T-s diagram.



Basic components of a gas turbine power plant

Operation 1-2 -- Rev. Adiabatic compression (isentropic)
Operation 2-3 Constant pressure heat supply
Operation 2-3 : Rev. Adiabatic Expansion (isentropic)
Operation 3-4 : Constant pressure heat rejection

Classification of Gas Turbines

Constant pressure combustion gas turbine :

(a) Open cycle constant pressure gas turbine

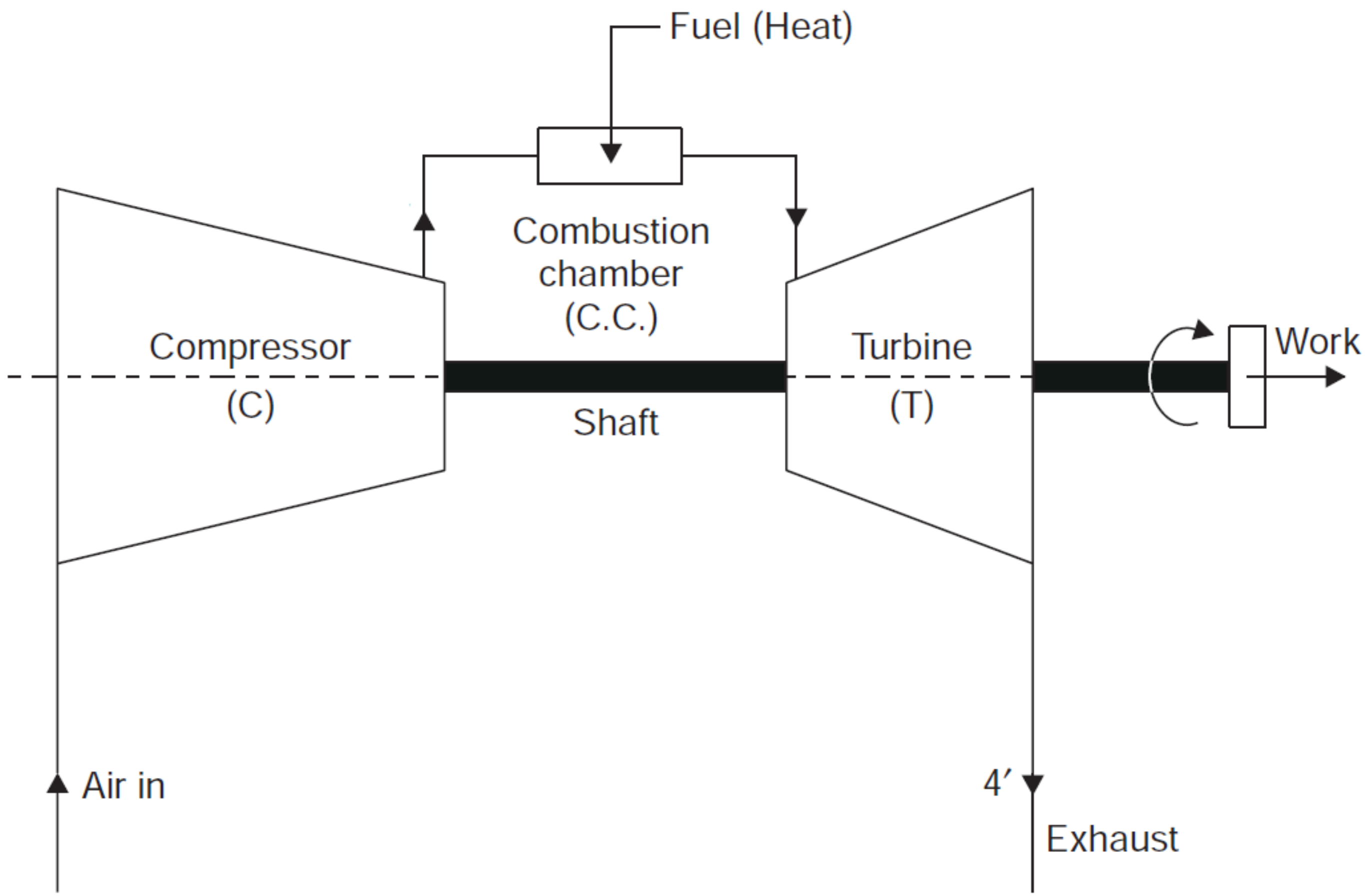
(b) Closed cycle constant pressure gas turbine

The following are the major fields of application of gas turbines :

1. Aviation
2. Power generation
3. Oil and gas industry
4. Marine propulsion.

The gas turbines have the following limitations : (i) They are not self-starting ; (ii) Low efficiencies at part loads ; (iii) Non-reversibility ; (iv) Higher rotor speeds ; and (v) Overall efficiency of the plant is low

Open Cycle Gas Turbine—Actual Brayton Cycle



Advantages of Gas Turbine

1. The mechanical efficiency of a gas turbine is quite high as compared with I.C. engine since the I.C.
2. A gas turbine does not require a flywheel as the torque on the shaft is continuous and uniform
3. The weight of gas turbine per H.P. developed is less than that of an I.C. engine.
4. The gas turbine can be driven at a very high speeds
5. Because of low specific weight the gas turbines are particularly suitable for use in aircrafts.

Disadvantages of Gas Turbine

1. The thermal efficiency of a simple turbine cycle is low (15 to 20%) as compared with I.C. engines (25 to 30%).
2. With wide operating speeds the fuel control is comparatively difficult.
3. Due to higher operating speeds of the turbine, it is imperative to have a speed reduction device.
4. It is difficult to start a gas turbine as compared to an I.C. engine.
5. The gas turbine blades need a special cooling system

Work Ratio (r_{bw})

Work ratio is defined as the *ratio of net work output to the work done by the turbine.*

$$\text{Work ratio} = \frac{W_T - W_C}{W_T}$$

$$\begin{bmatrix} \text{where,} & W_T = \text{Work obtained from this turbine,} \\ \text{and} & W_C = \text{Work supplied to the compressor.} \end{bmatrix}$$

Back work ratio :

It the ratio of –ve work and +ve work. Or Compressor work and turbine work

$$r_w = 1 - r_{bw}$$

Efficiency of simple gas turbine

$$\eta_{\text{air-standard}} = 1 - \frac{1}{(r_p)^{\frac{\gamma - 1}{\gamma}}}$$

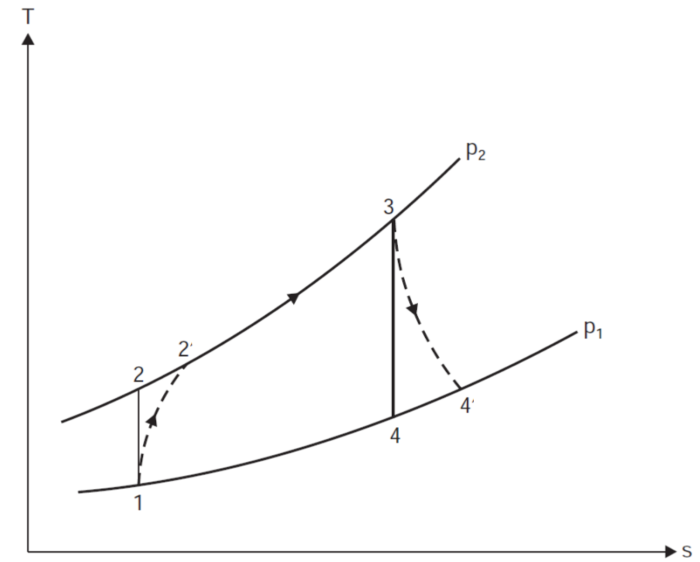
Compressor isentropic efficiency

$$Compressor\ isentropic\ efficiency(\eta_{comp})$$

$$= \frac{work\ input\ required\ in\ isentropic\ compression}{Actual\ work}$$

$$= \frac{isentropic\ work}{Actual\ work}$$

$$= \frac{(h_2 - h_1)}{(h_{2'} - h_1)} = \frac{c_p(T_2 - T_1)}{c_p(T_{2'} - T_1)} = \frac{(T_2 - T_1)}{(T_{2'} - T_1)}$$



$$Turbine\ isentropic\ efficiency(\eta_{comp})$$

$$= \frac{Actual\ work}{isentropic\ work}$$

$$= \frac{(h_3 - h_{4'})}{(h_3 - h_4)} = \frac{c_p(T_3 - T_{4'})}{c_p(T_3 - T_4)} = \frac{(T_3 - T_{4'})}{(T_3 - T_4)}$$

Thermal Efficiency of Gas Turbine Plant

- The net work of a gas-turbine cycle is the difference between the turbine work output and the compressor work input, and it can be increased by either decreasing the compressor work or increasing the turbine work, or both

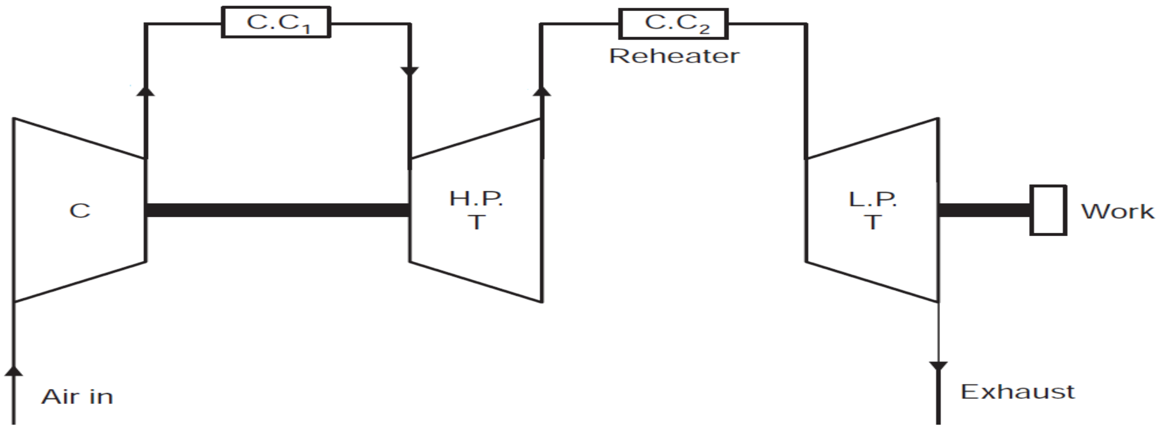
Methods for Improvement of Thermal Efficiency of Open Cycle Gas Turbine Plant

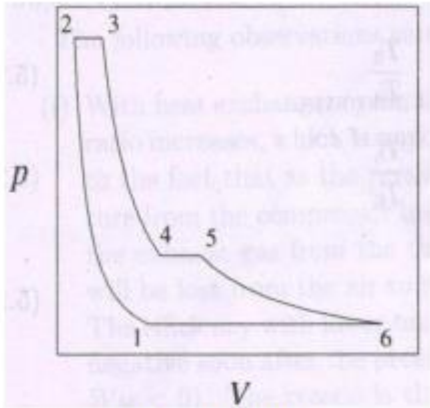
1. Intercooling
2. Reheating
3. Regeneration

Reheating

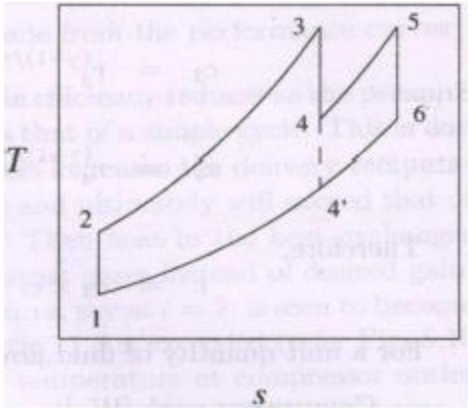
The output of a gas turbine can be amply improved by expanding the gases in two stages with a reheater between the two as shown in Fig. . The H.P. turbine drives the compressor and the L.P. .

1. increase in turbine work
2. No change in compressor work
3. increases in net work
4. increases in heat supply





P-V diagram



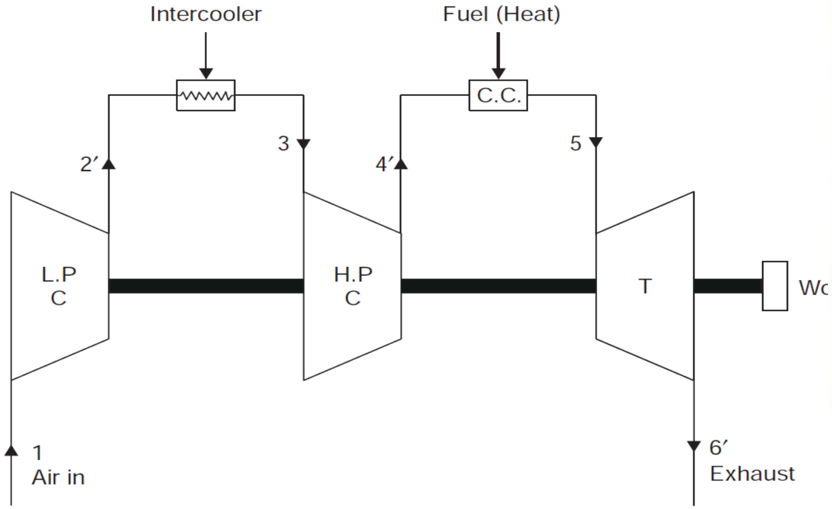
T-S diagram

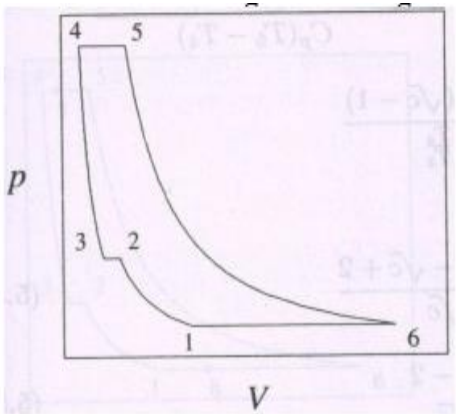
Efficiency is less due to small temperature operating range.

scope for regeneration

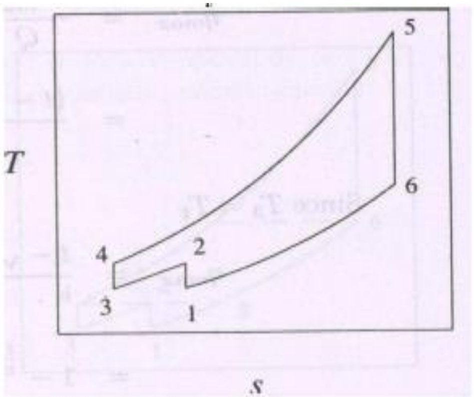
Intercooling:

A compressor in a gas turbine cycle utilizes the major percentage of power developed by the gas turbine. The work required by the compressor can be reduced by compressing the air in two stages and an intercooler between the





P-V diagram



T-S diagram

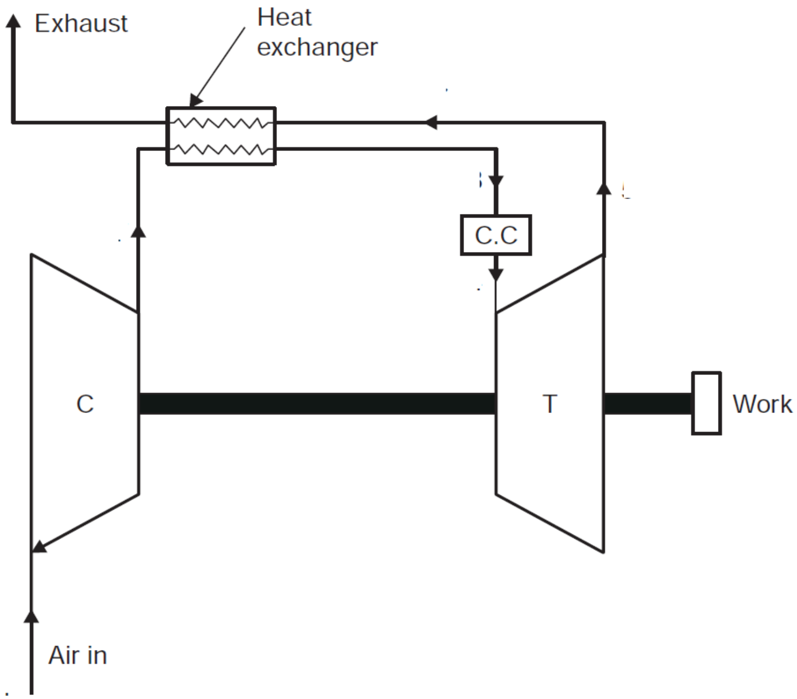
1. No change in turbine work
2. Decrease in compressor work
3. increases in net work
4. increases in heat supply

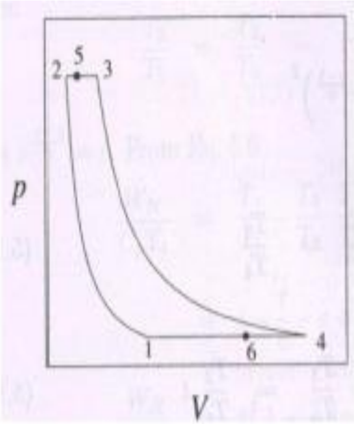
scope for regeneration

Because of the lower compressor outlet temperature, the fuel flow rate to obtain a given turbine inlet temperature will increase. Therefore, the thermal efficiency of the intercooled cycle will less than that of a simple cycle.

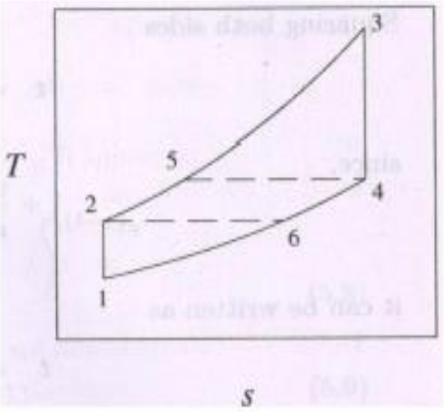
Regeneration

The exhaust gases from a gas turbine carry a large quantity of heat with them since their temperature is far above the ambient temperature. They can be used to heat the air coming from the compressor thereby reducing the mass of fuel supplied in the combustion chamber. Fig. shows a gas turbine plant with a regenerator.





P-V diagram

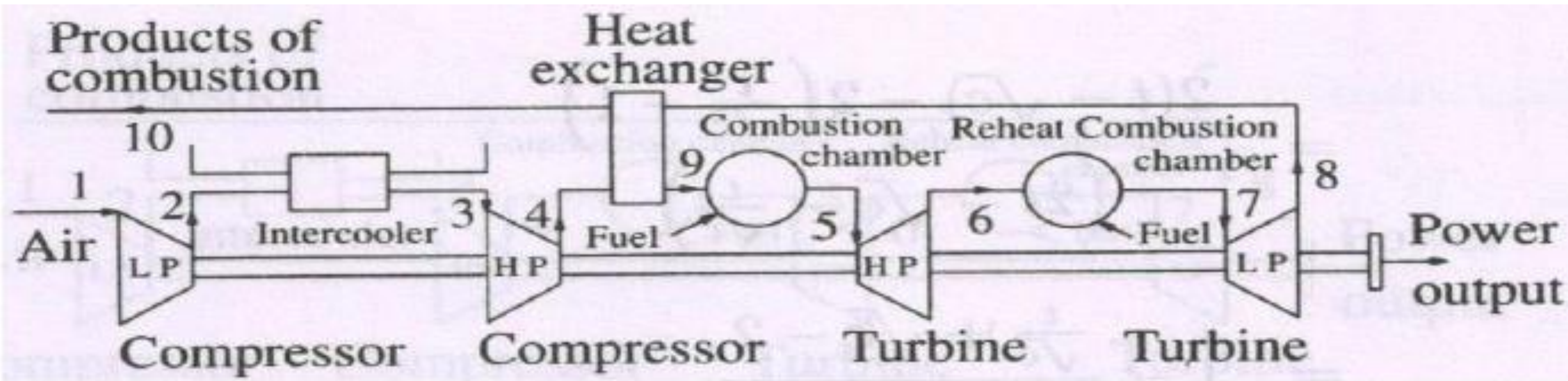


T-S diagram

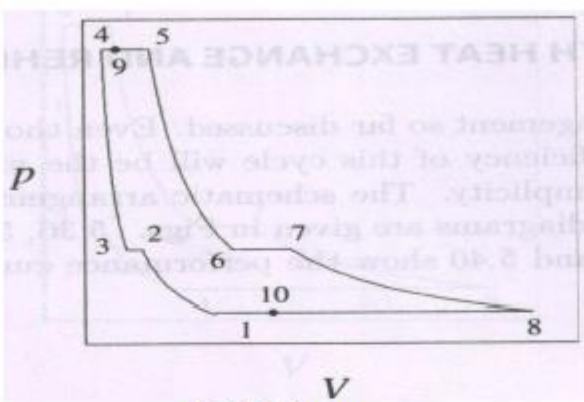
1. No change in turbine work
2. No change in compressor work
3. No change in net work
4. Decreases in heat supply
5. Increases in efficiency

- Efficiency increases with increase in T ,i.e. it is dependent upon maximum cycle temperature.
- Efficiency increases with decrease in pressure ratio.

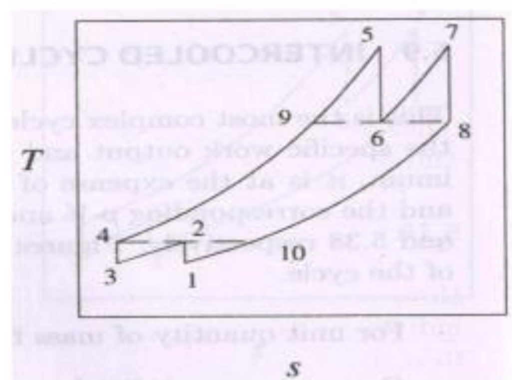
Intercooled cycle with heat exchange and reheat cycle



Arrangement of intercooled cycle with heat exchanger and reheat



P-V diagram



T-S diagram

Comparison between close cycle and Open cycle Gas Turbines

Close Cycle Gas Turbine	Open cycle Gas Turbine
1. The compressed air is heated in a heating chamber. Since the gas is heated by an external source, so the amount of gas remains the same.	The compressed air is heated in a combustion chamber. The products of combustion get mixed up in the heated air.
2. The gas from the turbine is passed into the cooling chamber.	2.The gas from the turbine is exhausted into the atmosphere.
3. The working fluid is circulated continuously.	3. The working fluid is replaced continuously.
4. Any fluid with better thermodynamic properties can be used.	4. Only air can be used as the working fluid.
5. The turbine blades do not wear away earlier, as the enclosed gas does not get contaminated while flowing through the heating chamber.	5.The turbine blades wear away earlier, as the air from the atmosphere gets contaminated while flowing through the combustion chamber.
6. It is best suited for stationary installation or marine uses.	6. It is best suited for moving vehicle.
7. Its maintenance cost is high.	7. Its maintenance cost is low.