The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Mechanical Engineering

NAME OF COURSE: - POWER PLANT ENGINEERING

CODE OF COURSE: - 315374

SEMESTER: - TYME-5K

SUBJECT TEACHER: - Mr. ANUP PRALHAD PATIL

The Shirpur Education Society's

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Department of Mechanical Engineering

NAME OF COURSE & CODE: - POWER PLANT ENGINEERING -315374	Academic Year: 2026-27
Program Code, Semester & Scheme: ME-5K	

CHAPTER:- 03:- Gas Power Plant and Waste Heat Recovery

COURSE LEVEL LEARNING OUTCOMES (COS):- Use knowledge and skills related to Gas Power Plant and Waste Heat Recovery properly in given situation.

Learning Hours	R-Level	U-Level	A-Level	Total Marks
10	4	4	6	14

Subject Teacher

Mr.Anup P.Patil

HOD ME 24/06/26

Mr.A.D.Patil

The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Program Name: Mechanical Engineering **Program Code:** ME5k

Name of Subject & Code : Power Plant Engineering (315374) **Semester :** Fifth **Date:-** 18/06/2026

QUESTION BANK

Unit - III Gas Power Plant and Waste Heat Recovery

Sr.NO	QUESTION	MSBTE QUE. NO	MARKS	EXAMINATION		BLOOSMS LEVEL
1	State the need of waste heat recovery in Thermal Power Plants.	QUE-01	2M		W-2025	CO-03,TLO-3.4,U
2	State any four components of gas turbine power plant.	QUE-01	2M	W-2025	S-2026	CO-03,TLO-3.2,R
3	State the four advantages of gas turbine power plant over other power plant.	QUE-02	4M		W-2025	CO-03,TLO-3.1,R
4	Explain need of co-generation with suitable example.	QUE-02	4M		S-2026	CO-03,TLO-3.5,U
5	Explain with neat sketch closed cycle gas turbine power plant.	QUE-03	4M	W-2025	S-2026	CO-03,TLO-3.2,U
6	Define Trigeneration and discuss the necessity of it.	QUE-04	4M		W-2025	CO-03,TLO-3.6,U
7	State applications of gas turbine power plant.	QUE-04	4M		S-2026	CO-03,TLO-3.1,R
8	Explain with neat sketch intercooling method used to improve the thermal efficiency of open cycle gas turbine power plant.	QUE-05	6M		W-2025	CO-03,TLO-3.3,U

Subject Teacher
Mr.Anup P.Patil

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Mr.Amol D.Patil

Unit-3 :- Gas Power Plant and Waste Heat Recovery

TLO-3.1 – Introduction to Gas Turbine Power Plant.

A Gas turbine is a type of internal combustion engine that convert the energy from the burning fuel into mechanical energy.

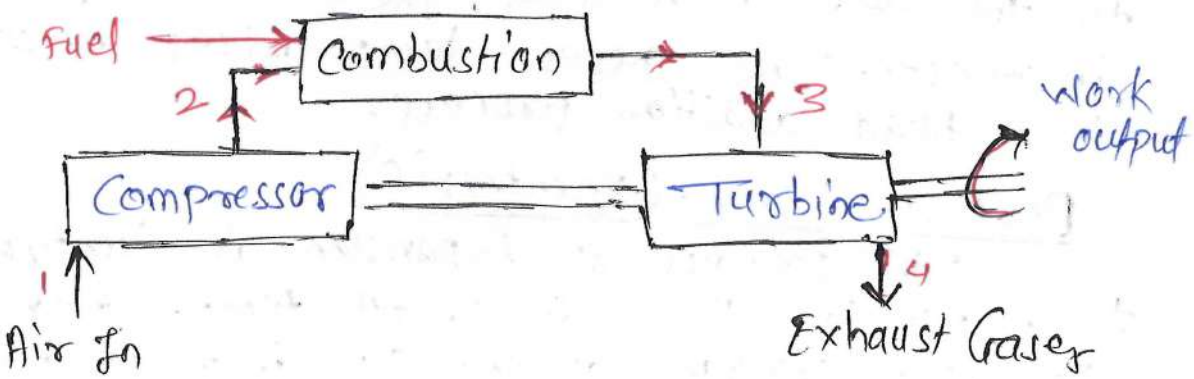
The gas turbine has low weight to power ratio hence gas turbine are extensively used to drive avation system of all kind in aircraft system.

The gas turbine power plant is known for its high efficiency, compact design and quick startup capabilities, making it widely used in industry.

* Classification of Gas Turbine:-

1. Continuous Combustion - (Constant Pressure type)
2. The Expansion - (Constant Volume type)
3. Open & Closed cycle gas Turbine.
4. According to the thermodynamic working Cycle:-
   - a) Brayton or Joule's cycle :- (Const. Pressure)
   - b) Atkinson cycle :- (Const. Volume)
   - c) Ericsson Cycle :- (Const. Pressure Gas using several intercooler & Reheater)

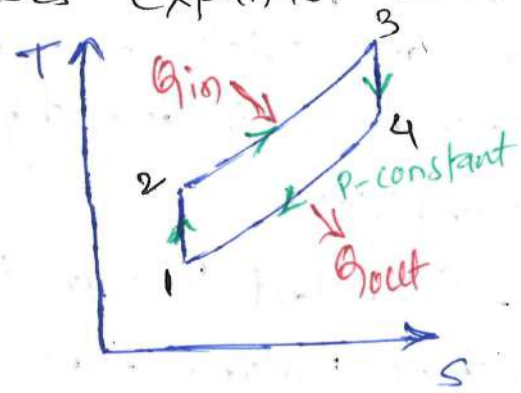
* Concept of Brayton Cycle:-

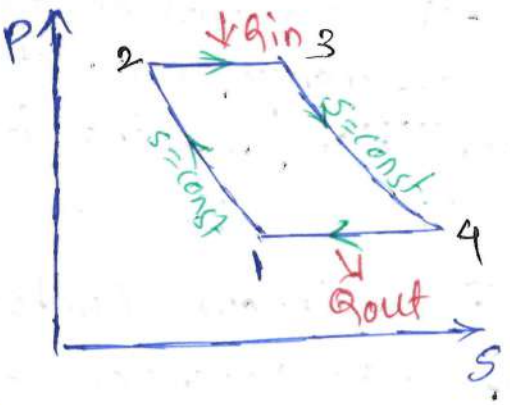


The Brayton cycle is the fundamental thermodynamic cycle that describes the operation of a gas turbine engine, commonly used in gas turbine power plant, jet engine and combined cycle system.

The cycle entails compressing outside air combining with fuel & then lightling the resulting mixture which expands and generates power.

A compressor draw in low pressure air which is then compressed fuel is combined with compressed air and burned. The resultant hot gases expands as they enter the turbine.





Process:- 1-2 (Isentropic):-

The compressor process is isentropic Here the gas temp. slightly increase as a result of compression.

The gases volume decrease because of the compression process:

Process:- 2-3 - (Isobaric):-

It is the process of Heat addition due to the addition of Heat, there is a slight volume increase. The gases temp. riser because it is a head addition process.

Process:- 3-4 - (Isentropic)

The process of Expansion is isentropic due to expansion there is small temp. drop in the area. The volume of the gas increare because

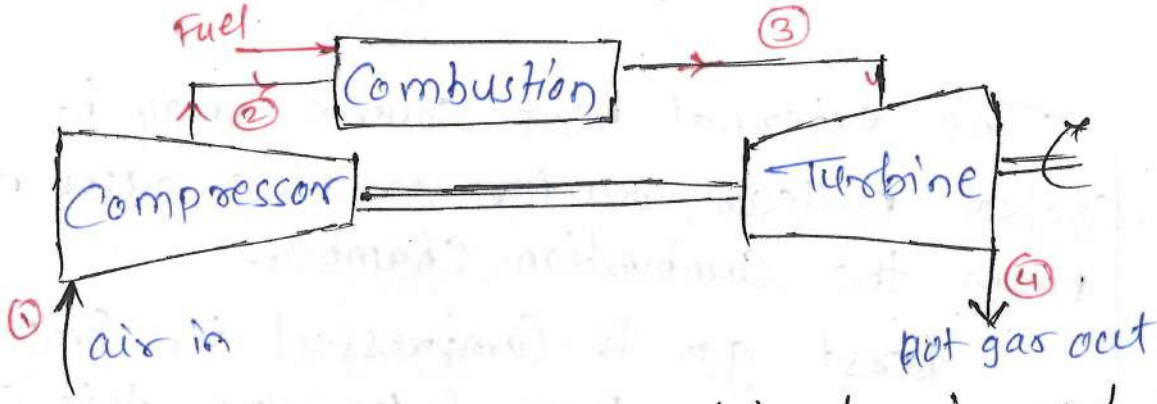
it is expanding during the process.

Process:- 4-1 - (Isobaric):-

It is the process for heat rejection. Heat rejection causes a slight volume reduction. The gases temp. drops because it is a heat rejection process.

TLO - 3.2 - Arrangement of Open and Closed cycle with Constant pressure gas turbine power plant:-

* Constant Pressure open cycle Gas Turbine:-



- The Compressor takes in ambined air and Compressed it to raises it pressure and temp. and delivered to combustion chamber where fuel is automiser through an injector & burned.

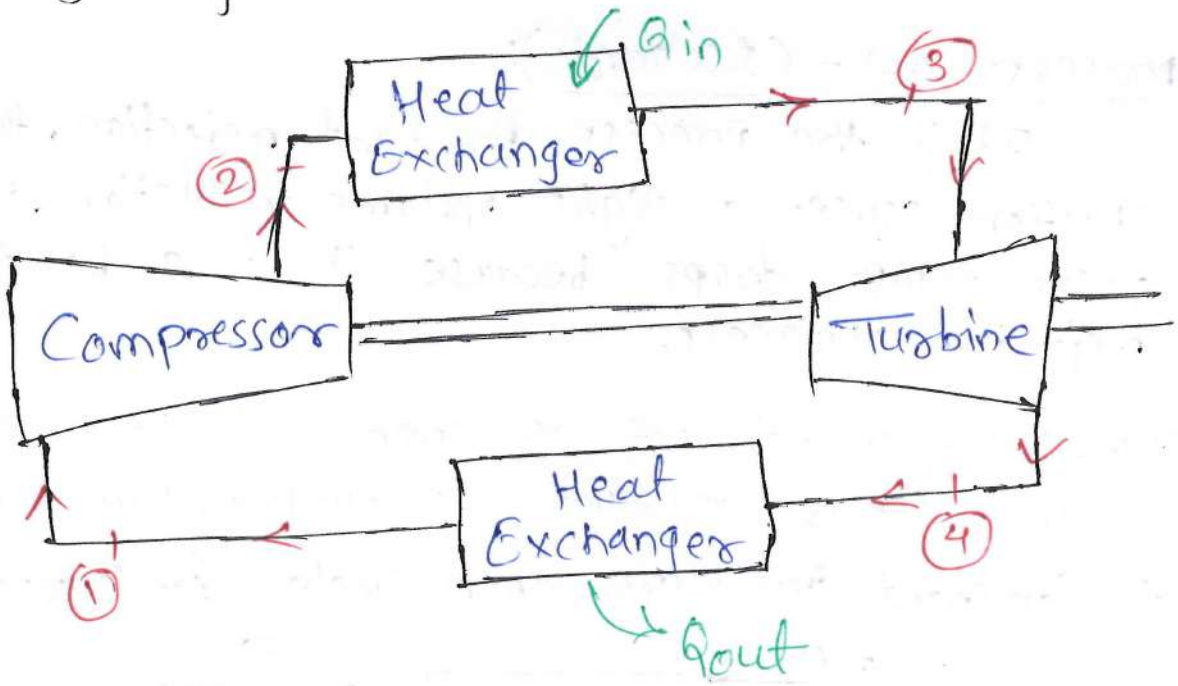
- This combustion process occurs ready at constant pressure, Due to the combustion heat is added to the working fluid and its temp. is raised.

* Constant Pressure Closed Cycle Gas Turbine:-

The idea of closed cycle gas turbine plant was originated and development in switzerland in the year 1935.

In closed cycle gas turbine fuel is not brought in direct contact with Compressed gas, but the working gas coming out of Compressor is directly heated at Constant Pressure in heat

Exchanger by an external heat source.



The external heat source may be gases cooled nuclear reactor or flue gases resulting from the combustion chamber.

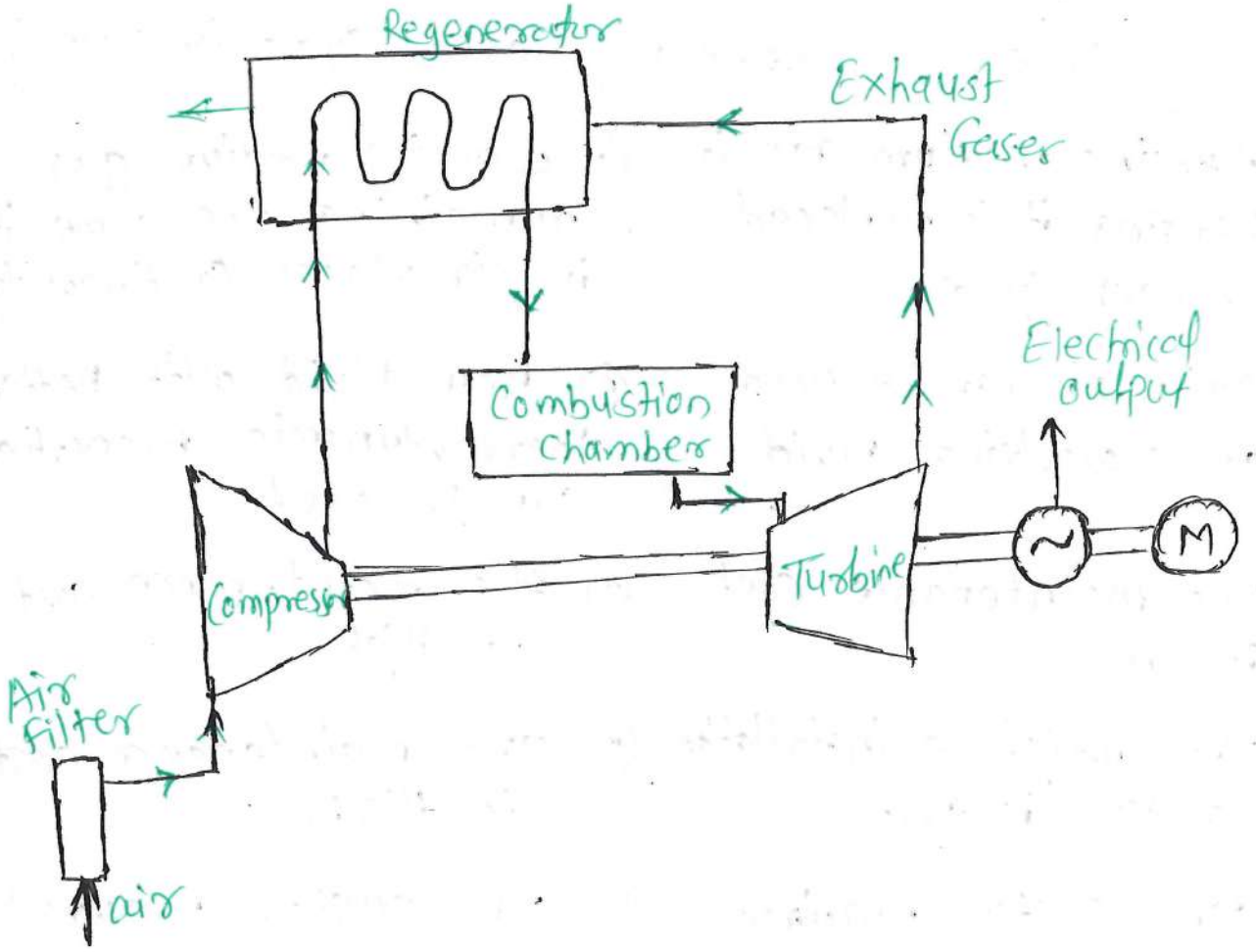
First gas is Compressed in Compressor which increase temp. & pressure, this Compressed gas is passed through the heat exchanger, where heat is added at constant pressure the Compressed gas leaving the heat exchanger is passes through the gas turbine. the expansion of gas takes place & reduce pressure and temp. then exhaust gas is passed through pe cooler before it enters gas is passed through pre cooler before it enters the Compressor to repeat cycle of operation.

The working gas may be air, helium, orgon, Carbondioxide & so on.

* Comparison of Open Cycle & Closed Cycle Gas Turbine:-

Open Cycle Gas Turbine	Closed Cycle Gas Turbine
① Working medium gas is changing it is replaced for each cycle.	① working medium gas remaining the same it is circulated continuously.
② Only air can be used as a working fluid	② Any fluid with better thermodynamic properties can be used.
③ It's maintenance cost is low	③ Its maintenance cost is High.
④ The weigh of installation per KW is less.	④ The maintenance cost is High.
⑤ The system required less space.	⑤ The system required more space.
⑥ Since the turbine exhaust is discharge into atmosphere it is best suitable for moving vehicle.	⑥ since exhaust is ~~exceeded~~ cooled by circulating water it is best suited for stationary installation marine use.
⑦ The turbine blades wear away earlier as it gets contaiminated with air.	⑦ It avoid erosion of turbine blade due to contaminatted gases and Fouling of Compressor blade.

TLO 3.3 - Component of Gas Turbine power plant and its Function:-



① Compressor:-

The Compressor is an apparatus used to increase the pressure of air taken from the atmosphere. In gas turbine power plant rotatory type Compressor are generally used.

The air at atmospheric pressure is drawn by the compressor through an air filter which remove the dust from the air.

The rotatory blades of the compressor push the air between the stationy blades to increase the pressure. Therefore the air at high pressure is available at the output of the Compressor.

(2) Regenerator:-

The regenerator is an apparatus which recover the heat from the exhaust gases of the gas turbine. The regenerator consist of nest of tubes contained in a shell.

The exhaust gases are passed through the regenerator before removing to the atmosphere. The compressed air from the compressor passes through the tubes of generator on its way to the combustion chamber.

(3) Combustion Chamber:-

In combustion chamber, the compressed air combines with fuel and the resulting mixture is burnt.

The greater the pressure of air, the better the fuel air mixture burns.

In the combustion chamber heat is added to the compressed air by burning of the fuel.

Consequently the combustion chamber attain a very high temp (about 1700°C). The gases produced by the combustion are suitable cooled to 700°C to 800°C. and the delivered to the gas turbine.

(4) Alternator:-

The gas turbine drives the alternator. The alternator convert the mechanical energy of the turbine into electrical energy.

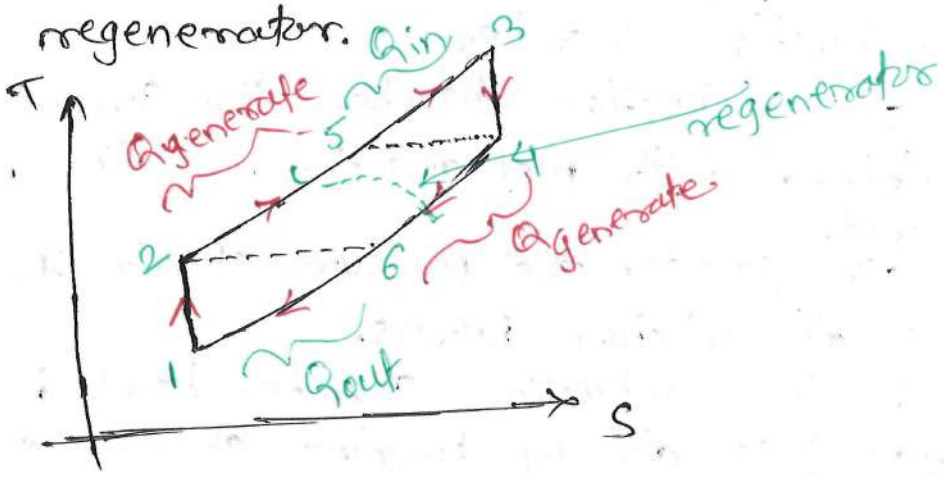
(5) Gas Turbine:-

The gas turbine is a device which convert heat energy of hot gases into mechanical energy. The product of combustion consisting of a mixture of gases at high temp & pressure are expanded in the gas turbine and does the mechanical works. i.e. it convert the heat energy into mechanical energy.

TLO-3.4- method to improve the thermal efficiency of a simple open cycle constant pressure gas turbine power plant:-

* Gas turbine with Generator:-

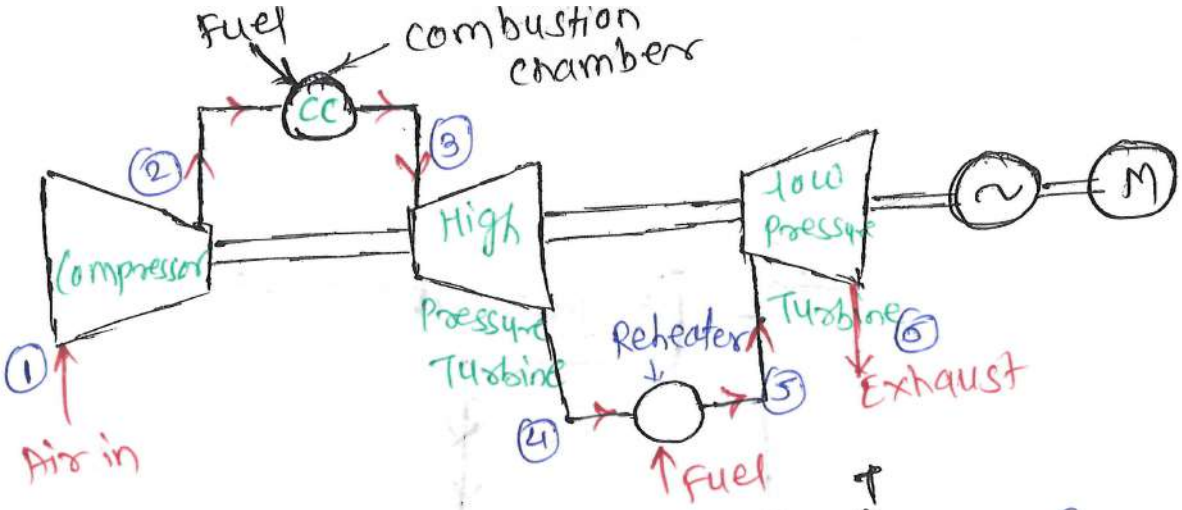
The temp. at the exhaust of the gas turbine is higher than the temp. of the air at the exist of the compressor. In order to utilize the heat energy of the exhaust of the turbine which is a waste to the atmosphere the compressed air is heated in a heat exchanger called regenerator.

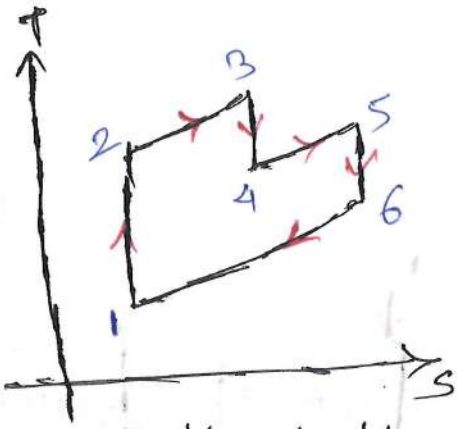


In the generation process there is a reduction in heat supplied to the gas but there is no effect on the turbine and compressor work therefore, the generation will not increase the work ration in the turbine but the efficiency of the turbine increase in the generation process.

* Gas Turbine cycle with Reheating:-

A common ~~th~~ method of increasing the means temp. of heat reception (addition) is to reheat the gas after it has expanded in a part of the gas turbine. By doing so the mean temp. of heat rejection is also increased resulting in a decrease in the thermal efficiency of the plant.





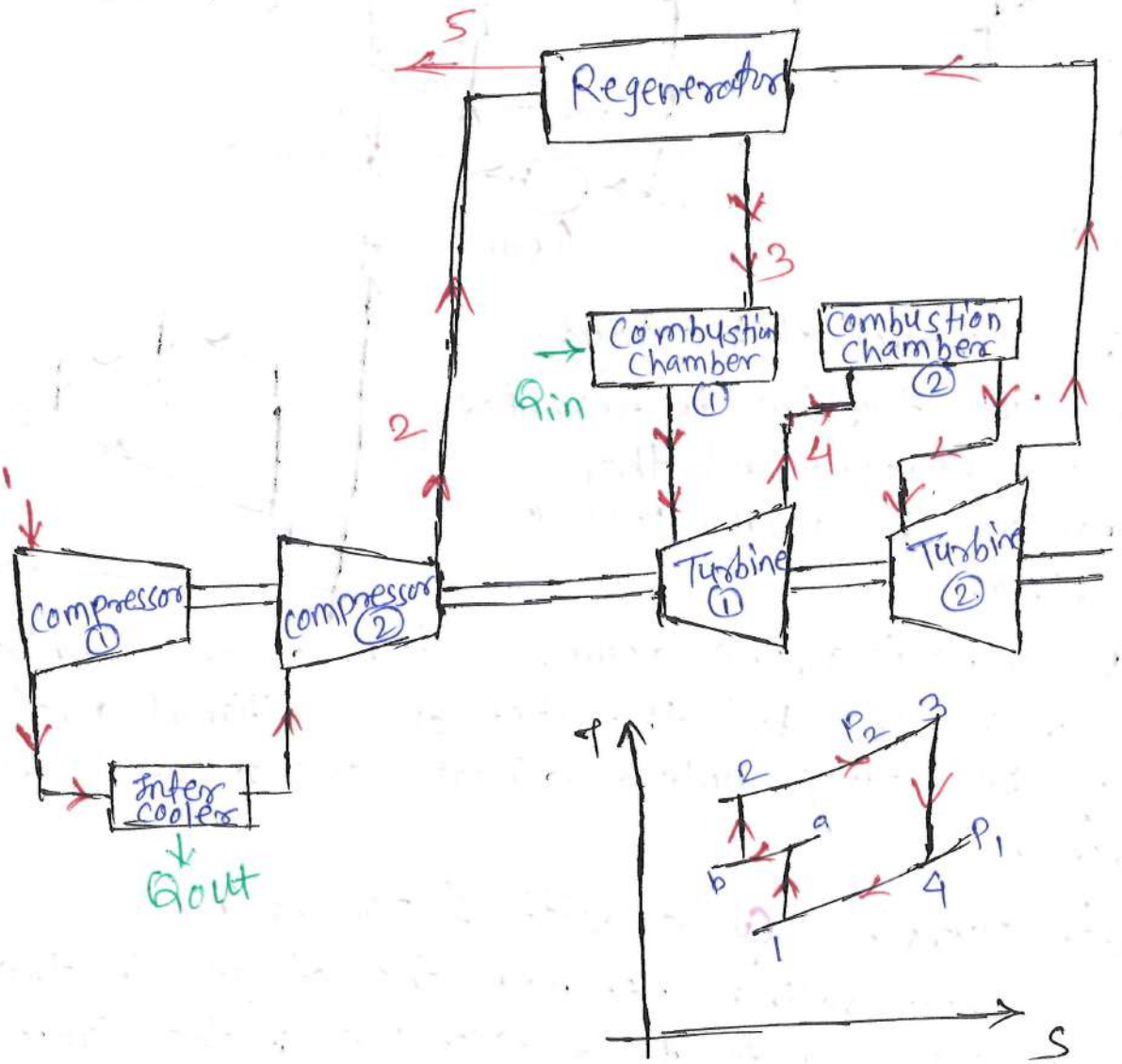
The exhaust of the high pressure turbine is reheated in a reheater and then expanded in a low pressure turbine.

By reheating, the power output of the turbine is increased but the cost of additional fuel may be heavy unless a heat exchanger is also used.

* Gas Turbine Cycle with Intercooling :-

Intercooling between the stages in the compressor leads to a decrease in the compressor work input thefore it will also help to increase the work ratio of the gas turbine plant resulting in a decrease in the thermal efficiency but the scope of generation will increase.

This can be achived by compressing the air in two or more number of stages by providing an intercooler in between the stages such as low of compression approaches to isothermal compression.



* Advantage of Gas turbine Power plant over other Power plant:-

(1) They are small in size, weight less and have low initial cost per unit output.
(2) They are easy to install with in short period.
(3) They are quick starting & smooth running
(4) They are capable of using a range of liquid and gaseous fuels including synthetic fuel.
(5) Water consumption is less compared to steam Power plant.

* Disadvantage of Gas Power plant over other Power plant:-

① An electric motor or an I.C. Engine is necessary for starting the plant. The starting motor must bring the Compressor well toward the operating speed, so starting is not simple as in the Case of other power plant.

② Gas turbine plant have less vibration when Compared with reciprocating engine of the same speed. However the high frequency noise from the Compressor is objectionable.

③ High temp impose severe restriction on the servicing condition of the plant.

④ Overall efficiency is low since two-thirds of the total power output is used for driving the Compressor.

⑤ The blades of turbine require special cooling method due to the severity of operating temp. & Pressure.

⑥ In practice the temp. at the entry of the turbine are as high as 1100°c - 1200°c.

⑦ They are incompatible with solid fuels.

TLO - 3.5 - Waste Heat Recovery in thermal Power plant:-

Waste heat recovery is the process of Capturing waste heat energy for beneficial purpose. Recaptured heat energy is potentially usefull for generating electricity. i.e. space heating, water supply & Green Houses.

Waste heat is heat energy which is generated in a process from combustion fuel or chemical reaction and then "dumped" into the environment even enough through it could still be reused for some useful and economic purpose.

The thermal power plant, the heat from the waste hot steam is recovered either in the form of sensiable heat or latent Head.

Heat losses:- Quality:-

Depending upon the type of process waste heat can be rejected at virually any temp. From that of chilled cooling water to high temp waste gases from an industrial furnace. Usually higher the temp. the quality and more cost effective is to the heat recovery.

Heat losses in Quantity:-

In any heat recovery situation it is essential to known the amount of heat recoverable and also how it can be used.

$$Q = V \times \rho \times C_p \times \Delta t$$

Q - the toal Heat content in KJ.
V - volume floco rate substance. (m^3/hr)
ρ - density of flue gases (Kg/m^3)
C_p - specific heat of working Fluid ($KJ/Kg^{\circ}C$)
Δt - temp. between in $^{\circ}C$ between the final highest temp. & initial temp.

* Need of Waste Heat Recovery:-

- A large quantity of flue gases at high temp. is produced by different parts of the heavy industry.
- At the present condition the heat energy of flue gases is wasted. If we are able to drop the heat and there by using the heat to produced steam an efficient electric power generation can be achived.
- The toatal heat generated in these industries is not utilizating full fledged but 45% is discharged through the exist gases which are from the preheater and through chimney and the gases which are releasing into atmosphere through this waste heat are NO_x, SO_x and particulates, carbon dioxide, mercury and vapourised heavy metals etc.
- Reduce environmental pollution by lowering heat losses and emissions
- Preheats feed water or combustion air, improving boiler performance.
- Conserves energy resource and supports sustainable operation.

* Opportunity for Waste Heat Recovery:-

① Low temp. waste heat source:-

Based on a 25° refrence most uncover waste heat is at low temp. about 60% of waste heat losses are at a temp below 230°C.

② System already including wate heat recovery that can be further optimized to reduce heat loss:-

Opportunity are also available to maximum quality at heat recovered since facilities are often to use dilution air to lower the temp. of waste heat steam. The extent of heat recovery system is often constrained by cost & temp. limit for the heat recovery steam.

③ High temp. System where heat recovery is less common:-

There are the segments where waste heat recovery is less common this is due to barrier such as chemical consistuent in the exchanger as well as limitation on economics of scale for small waste heat stream.

④ Alternate waste heat sources typically not considered for waste heat recovery:-

This focus on combustion and process exhaust gases, where as alternate source of waste heat were also found to be significant the alternative are heat radient, convicefed and condusfed from heat product as well as heat loss in side wall and after pyro-process where slag or after material are solidified to protect the vessel walls.

* Present Practices in Waste Heat Recovery in thermal Power plant:-

① Internal Recycling:-

Hot exhaust gases are used to pre-heat the incoming water and fresh air before they enters the boiler. This means the boiler doesn't have to work as hard.

② Special Fluids:-

For lower-temp. heat that water can't use, plants use special liquids that boil easily. This means the better doesn't behave The waste heat boils liquid to turn a second smaller turbine for extra electricity.

③ Super cooling (Advanced Pipes)

modern plant use special plastic coated pipe that don't rust. This lets them trap every last drop of heat from the chimney smoke saftey.

④ Sharing the Heat:- The worm water left over is sent to nearby towns for home heating or used to turn seawater into fresh driking water

TLO.3.6- Cogeneration :-

Co-generation is define as sequensial generation or combination of two energies form of useful energy from a single primary energy source used for the generation of electrical energy and as well as heat.

The engine waste half of the main energy due to surplus heat, by capturing the surplus heat combined heat and paver utilize heat that would be wasted in a standard power station potentially attaining a total efficiency range from 80 to 95%.

* Need of Co-generation:-

- In traditional power plant only 35-50% of the fuel energy is converted to electricity.
- Co-generation capturing and user thir waste heat boosting efficiency to 80-90%.
- meeting this demand separately increare fuel use cost and pollution.
- Co-generation reduce fuel use and lower green houser gar emission such as mercury, sulphur dioxide, Carbon dioxide.
- Co-geration reducer fuel consumption leading to lower energy bills and shorte payback periods on investment.

* opperturnities of Co-generation:-

The small scale sector occupies a position of prominence in the indian economy contributing to more than 50% of the industrial production in value addition terms.

- Improoving technical and operating efficiency of the existing plant.
- Replacing inefficient machinery with new energy efficient equipment.
- Adopting various mean of energy conservation.
- optional design and effective implement of Cogeneration project.

* Application of Cogeneration in Sugar Industry:-

① Steam Generation:-
Bagases is fed into a high pressure boiler and burned to generate high Pressure, high temp. steam.

② Electricity Generation:-
This high pressure steam is expanded through a steam turbine connected to generator to create electricity.

③ Process Heating:-
The lower- Pressure steam exiting or extracted from the turbine is still very hot. Instead of being wasted, it is piped directly into the sugar processing plant.

④ Juice Evaporation:-
This thermal energy is used to heat, boil and evaporate the sugarcane juice to crystallize it into sugar.

* Application of Cogeneration in Chemical and Petrochemical Industry:-
Chemical plant operates continuous, 24/7 manufacturing loops that require immense amount of high-Pressure steam for chemical Reaction, distillation column and raw material heating.

* Application of Co-generation in Textile & Fabric:-
Textile mills require a steady supply of low to medium pressure steam and hot water for processes like fabric dyeing, bleaching, washing, and Printing.

* Application of Co-generation in Food & Beverage Processing unit:-
Food Processing Facilites (dairies, breweries, meat processing plants, and canning Factories) have strict sterillization, cooking, pasteurization and cleaning protocols that demand continuous thermal Energy.

* Advantages of Cogeneration:-

1. Cogeneration helps to improve the efficiency of the plant.
2. cogeneration reduce air pollution due to emission of particular matter, nitrous oxides, sulphur dioxide mercury and carbon dioxide which would otherwise leads to greenhouse effect.
3. It reduce cost of production and improve productivity.
4. Cogeneration system is more economical as compared to conventional power plant.
5. Cogeneration system helps to save water consumption and water cost.
6. It reduce fuel need reduce impart dependency.
7. Largest cost saving thus additional competative for industrial and Commercial user and affordable heat for domestic user.
8. Provide an Opportunity to increase the generation plant diversity & competition.

* Introduction to bagasse fired Boiler:-

1. Fuel Feeding:-
   Bagasse is transported via conveyor belt from the sugar mill directly to the top of the boiler. It is fed into the furnace using mechanical or pneumatic bagasse spreaders that distribute the fuel evenly across the combustion zone.
2. Suspension & Grate Burning:-
   Because bagasse is light, smaller particles burn instantly while floating in mid air. The heavier chunks fall onto a heavy duty moving metal grate at the bottom to complete combustion.

③ Moisture Evaporation:-
Highly pressurized, preheated air is blasted into the furnace. This hot air instantly dries out the wet bagase so it can catch fire immediatly.

④ Steam Generation:-
The intense heat from combustion turn the water inside the boilers tightly packed steel tubes into high pressure, superheated steam.

* Types of Bagasse Boilers:-

① spreader stroker Boiler (Travelling Grate):-
The most common commercial type. The bagasse is thrown into the air across a slowly moving grate. The ash is automatically moved to the front and dumped into a collection happer without stopping the boiler.

② Fluidized Bed Combustion (FBC) Boiler:-
An advanced highly efficient design where bagasse is fed into a hot, churning bed of boiling sand and air. This ensures excellent heat transfer and allows the boilers to burns very wet or low quality bagasses smoothly.

* Advantages of bagasses fired Boiler:-

① Free fuel source:- It runs entirely on crushed sugar cane waste, Completely eliminated fuel and transportation cost for the factory.

② 100% eco-friendly:- It burn natural plant biomass, creating a closed carbon loop that is completely clean & carbon neutral.

③ Total Energy Independence:-
The boiler generates all the electricity and process steam needed to power of the entire sugar mill on its own.

TLO-3.7. Trigeneration:-

Trigeneration is the production of Combined cooling heat & power inplant from a single generator or process. The trigeneration system produce electricity and useful heat which utilized for hot water, space heating or steam production. as well as energy efficient cooling.

(1) Tata Power Trigeneration plant-
Tata power trombay thermal Power station.

(2) IIT Madras Research Park
(3) AIIMS Hospital - New Delhi
(4) ONGC Hazira plant - Gujarat
(5) Bhabha Automic Research centre, Mumbai.

* Need of Trigeneration Plant:-

- Trigeneration deals with study of simultaneous generation of electricity and useful heating and cooling form of combustion of biomass fuel or solar heat collectors.
- In a trigeneration system, the supply of high temp. heat first drives a gas or Stream turbine powered generator and resulting low temp. waste heat is then used for water.
- Gas fired generator are used to produce electricity. They by product is waste heat which is then directed to absorption chillers and boilers for space cooling, hot water and related purpose.
- The combination of distributed generation of power and utilization of waste heat can provide a sustainable solution to meet the high demand for refrigeration in the region.

* Opportunities of Trigeneration:-

- Trigeneration technology is a transformative cost effective solution that enable localized reliable and stable power supply. using a single fuel.
- This technology has been sucessful in international market in enhanceing operating efficiency of an industrial application by at least 60%. saving industries and institutions 30-40% in operating energy cost and reducing greenhouse gas emission by upto 30%. due to inhearnt efficiency in energy generation.
- The technology has direct relevence to hostel hospital, airport, retail office and integrated residential / commercial complexes that require all forms of building energy simultaneously.
- The demand for air. conditioning, heating and electricity in these building and large institution can be meet by installing trigeneration system that not only reduce carbon emission.
- Residential complex and large commercial establishment. therefore must adopt gas- based trigeneration to ensure simultaneously generation of power heating and cooling while saving on their electricity bills and carbon emission.
- At 60-80% efficiency, trigeneration system which can use natural gas as fuel are highly efficient and can be installed, started and stop quickly.

* Advantages of Trigeneration system:-

① saving on Greenhouse Gases:-
Producing electricity on site using gas produce approx. 30% less green house gases, then using power from grid in NSW for a equal amount of power output.

② saving on energy cost:-
Using trigeneration to produce electricity and specifically when using gas to run the generator and produce heat for the absorption chiller instead of power from the grid to run the air conditioning plant, saving on energy cost in the order of upto 30%, can be achived depending on relatively price of gas and electricity to the site.

③ High energy efficiency:-
utilizes upto 80-90% of the fuel energy by producing electricity, heating and cooling from the same source.

④ Compact & Space saving:-
Trigeneration system are often modular and require less space than installing separator system.

⑤ Replacing thermal Energy:-
Using Natural gas replace dependence on coal while nullifying the need for additional energy input for heat and cooling generation. Trigeneration system can hence reduce an establishment greenhouse gas emission by upto 50%.