

UNIT - II

Gas Turbine and Combined Cycle power plants

Brayton cycle analysis and optimization:-

Gas turbines usually operate on an open cycle.

Air at ambient conditions is drawn into the compressor, where its temperature and pressure are raised. The high pressure air proceeds into combustion chamber, where the fuel is burned at constant pressure.

The high temperature gases then enter the turbine where they expand to atmospheric pressure while producing power output.

Some of the output power is used to drive the compressor.

The exhaust gases leaving the turbine are thrown out (not be circulated) causing the cycle to be classified as an open cycle.

Brayton cycle / gas turbine history:-

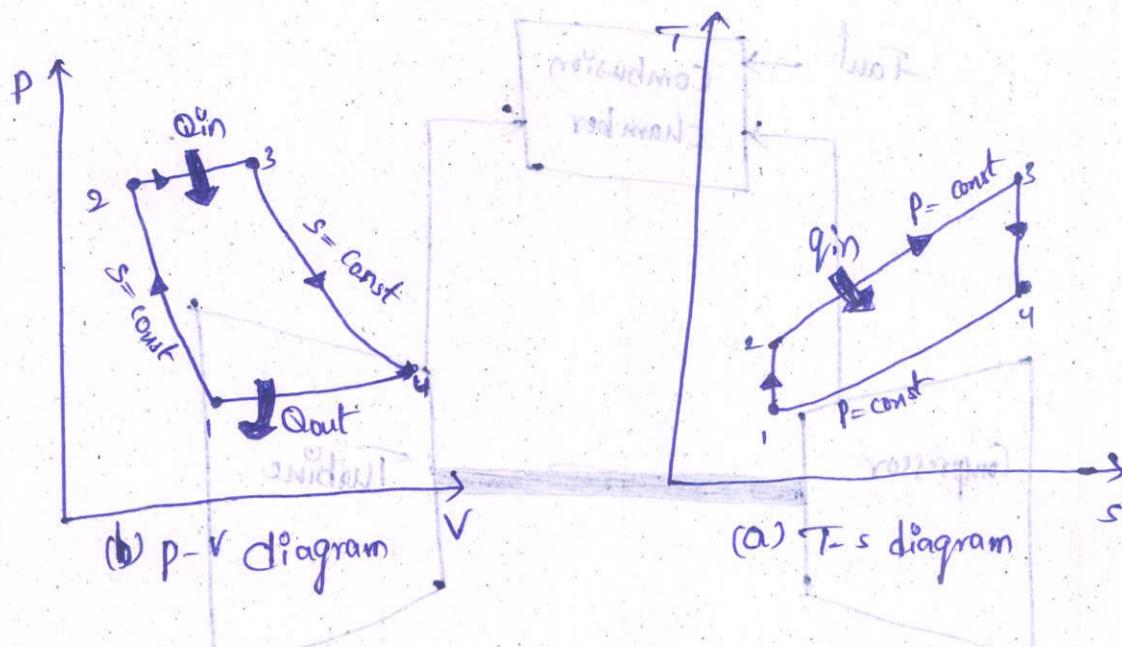
The basic gas turbine cycle is named for the Boston engineer George Brayton, who first proposed the Brayton cycle around 1870.

The Brayton cycle is used for gas turbines only where both the compression and expansion process take place in rotating machinery.

Brayton Cycle Components:-

- * Gas turbines usually operate on an open cycle
- * fresh air at ambient conditions is drawn into the compressor, where its temperature and pressure are raised.
- * The high-pressure air proceeds into the combustion chamber, where the fuel is burned at constant pressure
- * The resulting high-temperature gases then enter the turbine, where they expand to the atmospheric pressure through a row of nozzle vanes

Brayton Cycle



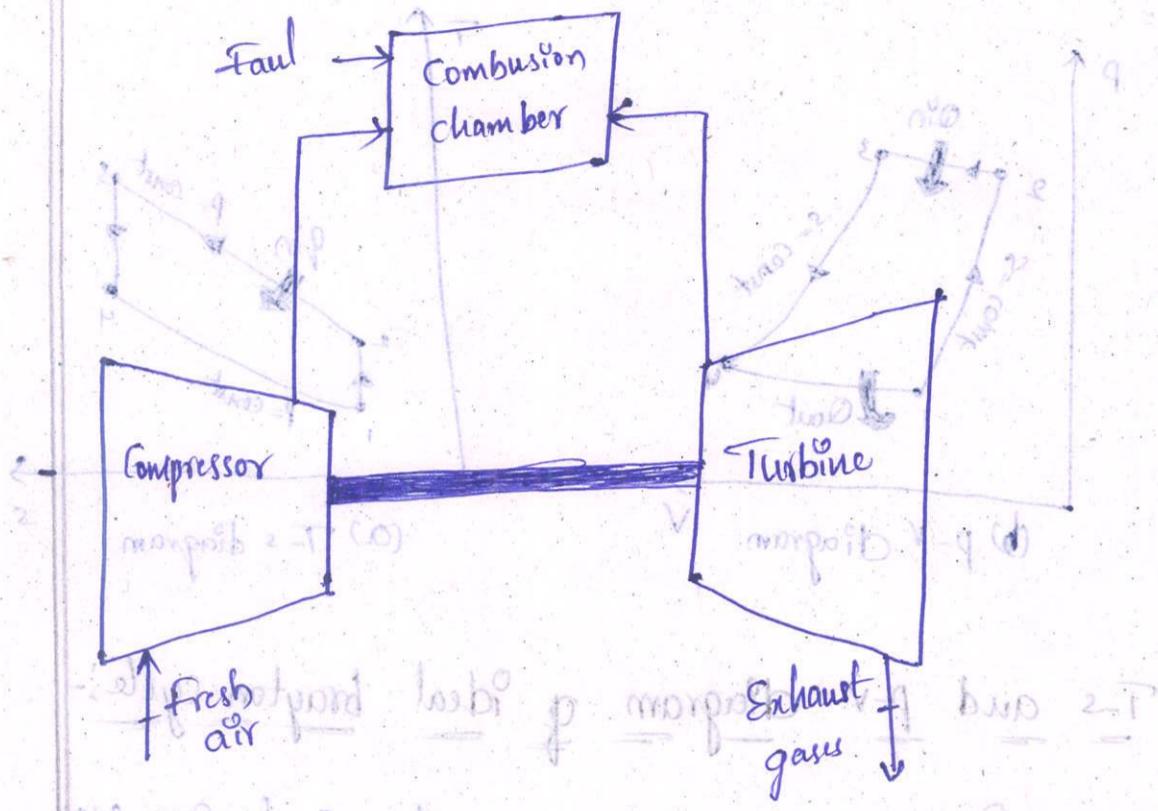
T-s and p-v diagram of ideal brayton cycle:-

- * All four processes of the brayton cycle are encountered in steady flow devices so they should be analyzed as steady-flow processes.
- * When the changes in kinetic & potential energies are neglected, the energy balance for a steady-flow process can be expressed on a unit-mass basis.
- * The thermal efficiency of an ideal Brayton cycle depends upon pressure ratio of the gas turbine & the specific heat ratio of the working fluid.
- * Specific ratio : A physical property of a material, the specific heat defined as the amount of heat required to raise a unit of mass of a substance one degree.
- * In brayton cycle

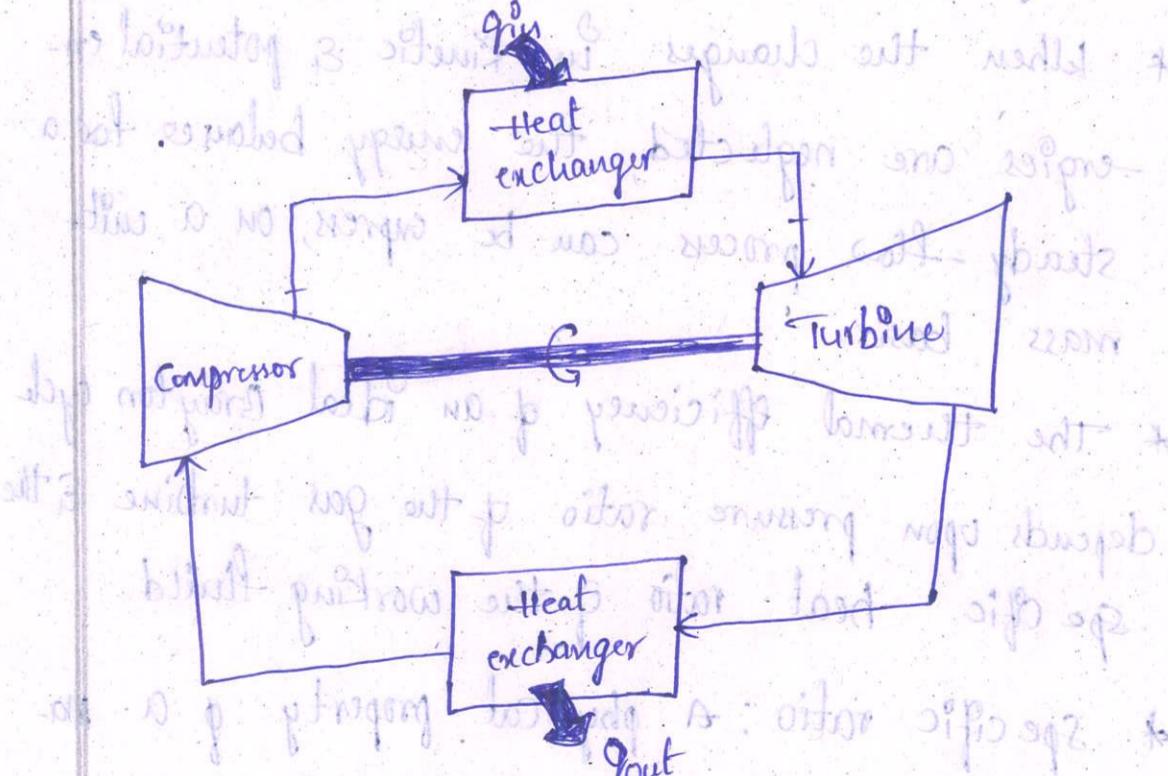
$$\tau_p = P_2 / P_1$$

unit-2, pg-3/15

Diagram of gas turbine engine



open cycle gas turbine



Closed cycle gas turbine engine

Efficiency

$$\eta = \frac{r_p(F-1)}{K} \quad (\text{for adiabatic process})$$

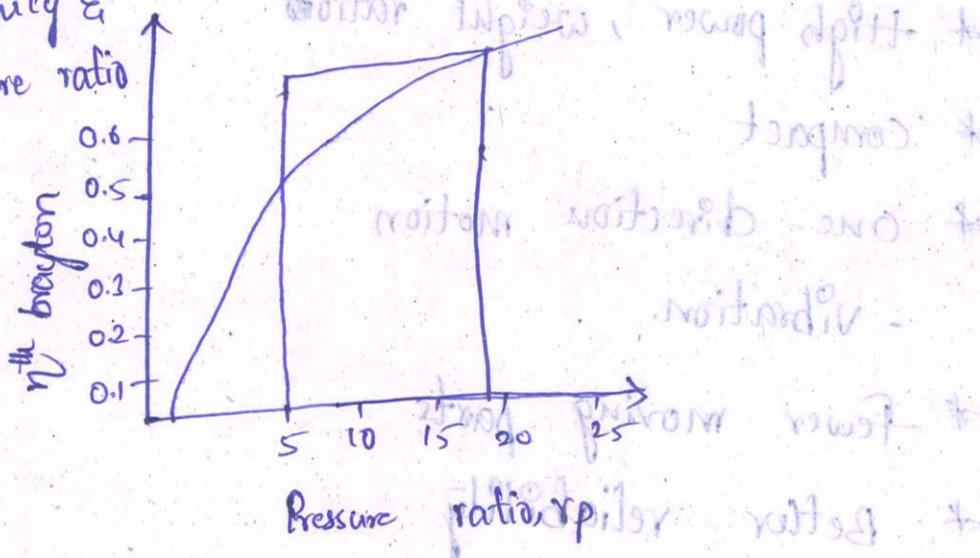
* In theory, as the pressure ratio goes up, the efficiency rises, the limiting factor is frequently the turbine inlet temperature.

* The turbine inlet temperature is restricted to about 1,700 K or 2,600 F.

Relation b/w

efficiency &

pressure ratio



Brayton cycle with Intercooling, Reheating & Regeneration

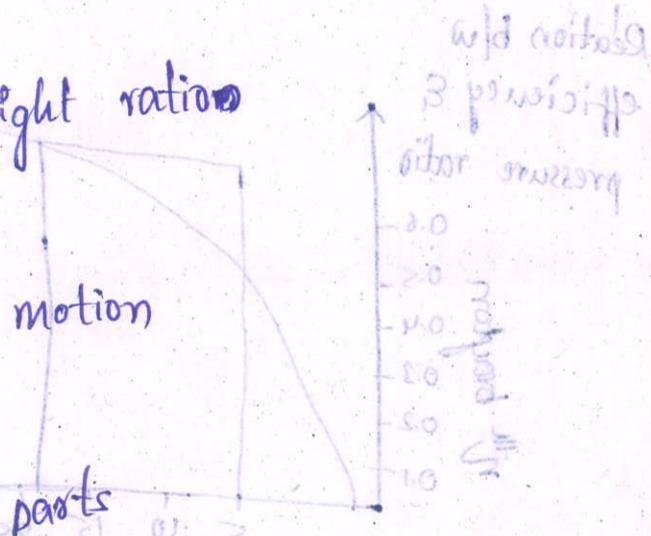
- * The net work output of a gas-turbine cycle can be increased by either:
 - decreasing the compressor work or
 - increasing the turbine work, or
 - Both

* the compressor work input can be decreased by carrying out the compression process in stages & cooling the gas in b/w using multi stage compression with intercooling

The work output of a turbine can be increased by expanding the gas in stages and reheating it in between utilizing a multistage expansion with reheating.

Advantages:-

- * High power , weight ratio
- * compact
- * one-direction motion
- vibration.
- * fewer moving parts
- * Better reliability
- * variety of fuels
- * low emissions



Disadvantages:-

- * Higher Cost.

* Components of gas turbine power plants:

A gas turbine is a machine delivering mechanical power or thrust. It does this using a gaseous working fluid. The mechanical power generated can be used by, for example, an industrial device.

The outgoing gaseous fluid can be used to generate thrust. In the gas turbine, there is a continuous flow of the working fluid.

Efficiency is 20 to 30%, whereas that of stream

Power plant is 38 to 48%. Major applications of

gas turbine

1. Aviation (self contained, light weight don't require cooling).

2. Power generation (modular, cost effective)

3. Oil and gas industry (cheaper supply of fuel & low installation cost)

4. Marine propulsion.

Hot gases move through a multi stage gas turbine.

Like in the steam turbine, the gas turbine

also has stationary and moving blades.

* guide the moving gases to the rotor blades

* adjust its velocity

The shaft of the turbine is coupled to a generator.

Working principle:-

* Air is compressed (squeezed) to high pressure

by a compressor.

* Then fuel and compressed air are mixed in a combustion chamber and ignited.

* Hot gases are given off, which spin the turbine wheels.

* Gas turbine burn fuels such as oil, nature gas and pulverized (powdered) coal.

* Gas turbines have three main parts

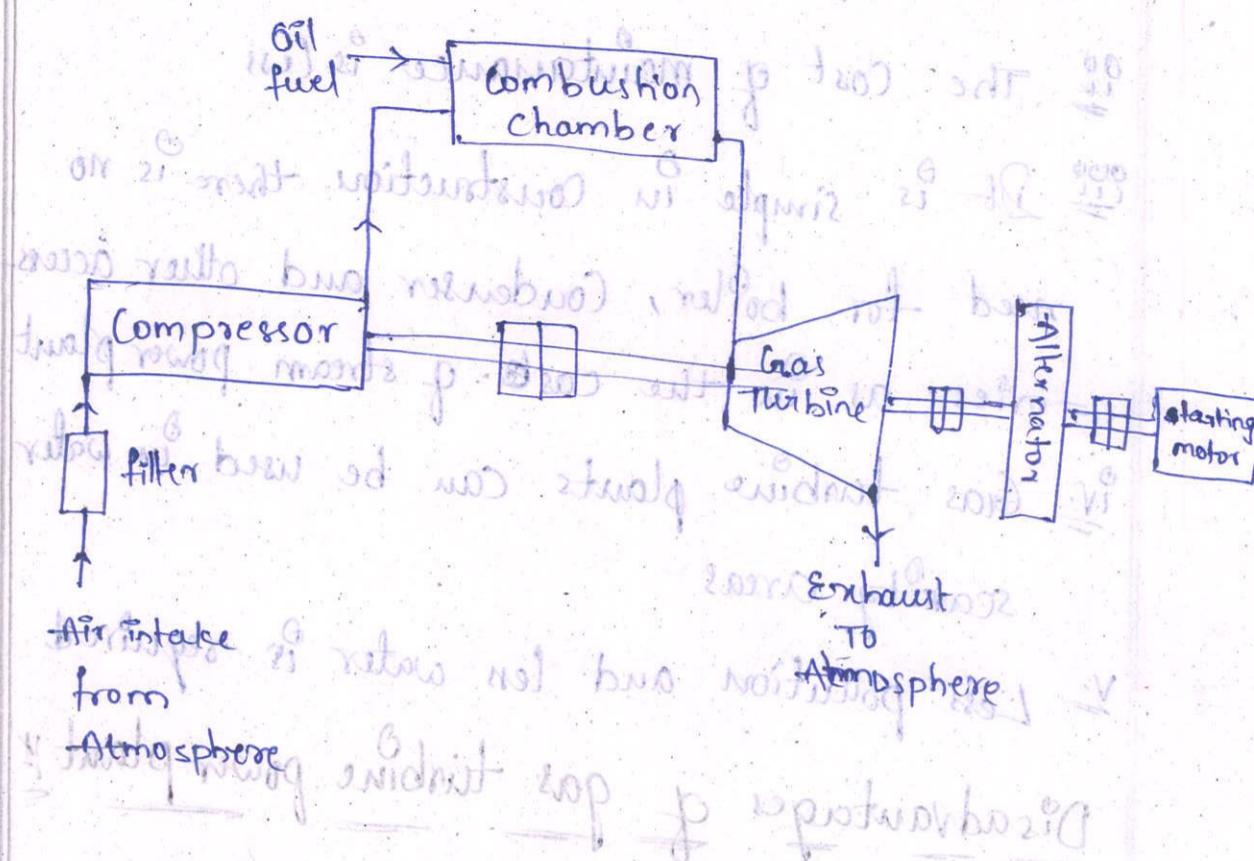
i. Air Compressor

ii. Combustion chamber

iii. Turbine

Simple gas turbine

will burn 3 min until whiper last p. separate



Energy flow diagram

coal, crude oil,

solar energy

petrol, diesel,

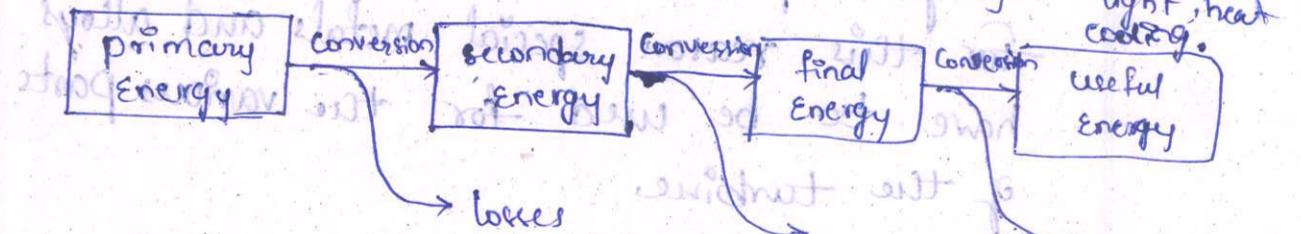
gas etc.

Energy received

by consumer

like Industry

useful service like
light, heat
cooling.



unit-2 pg - 9/15

Advantages of gas turbine power plant

i. storage of fuel requires less area & handling is easy

ii. The cost of maintenance is less

iii. It is simple in construction. there is no

need for boiler, Condenser and other accessories as in the case of steam power plant.

iv. Gas turbine plants can be used in water scarcity areas

v. Less pollution and less water is required

Disadvantages of gas turbine power plant

1. 66% of the power developed is used to drive the compressors. therefore the gas turbine unit has a low terminal efficiency.

2. The running speed of gas turbine is in the range of (40,000 to 110,000 rpm) and the operating temperature is as high as 1100 - 1200°C. for this reason special metals and alloys have to be used for the various parts of the turbine.

3. High frequency noise from the compressor is objectionable

* Combined cycle power plant:

- * The combined cycle power plant (or) combined cycle gas turbine, a gas turbine generator generates electricity and waste heat is used to make steam to generate additional electricity via a steam turbine.
- * A combined cycle power plant produces high power outputs at high power outputs at high efficiencies (Up to 55%) and with low emissions. In a conventional power plant we are getting 33% electricity only and remaining 67% as waste.
- * By using combined cycle power plant we are getting 68% electricity.

* Inner working of a combined power plant

- * A combined cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.

How a combined cycle power plant produces electricity

* Gas turbine burns fuel
The fast spinning turbine drives a generator
that converts a portion of the spinning energy
into electricity

* Heat recovery system captures exhaust
The HRSG creates steam from the gas turbine
exhaust, heat and delivers it to the steam
turbine
* steam turbine delivers additional electricity.

The steam turbine sends its energy to the
generator shaft where it is converted
into additional electricity.

Advantages of Combined cycle power-

* The efficiency of the combined cycle plant
is better or higher than the turbine cycle
or steam cycle plant. The efficiency of
combined cycle power plant will be of the
order of about 45 to 50%
* fewer moving parts and less vibration than
a reciprocating engine.
* very low toxic emissions

* Runs on a wide variety of fuels

* High operating speeds

DIs advantages of combined cycle power plant.

* Higher cost

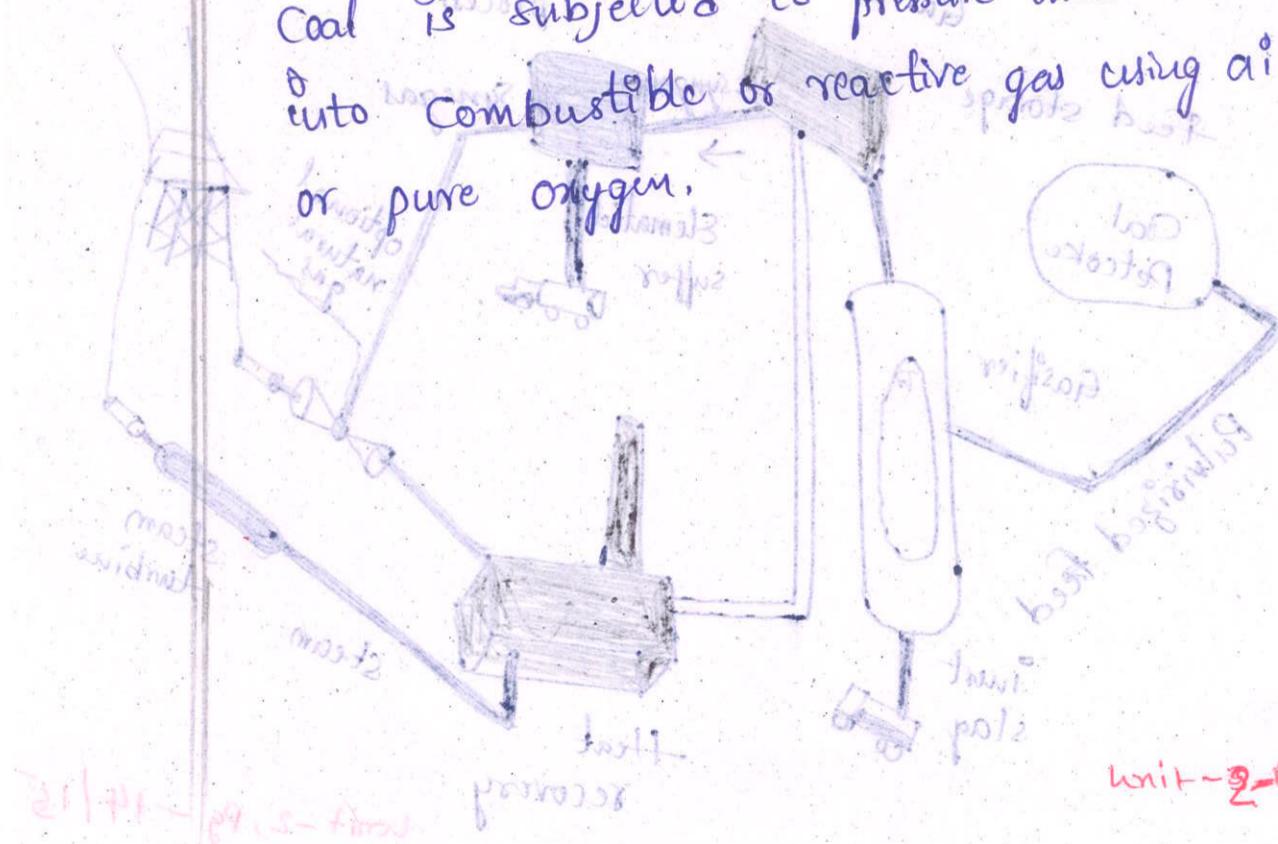
* Longer start-up

* less responsive to power demands

* shrill whining noise

Integrated Gasifier based combined cycle (IGCC) systems

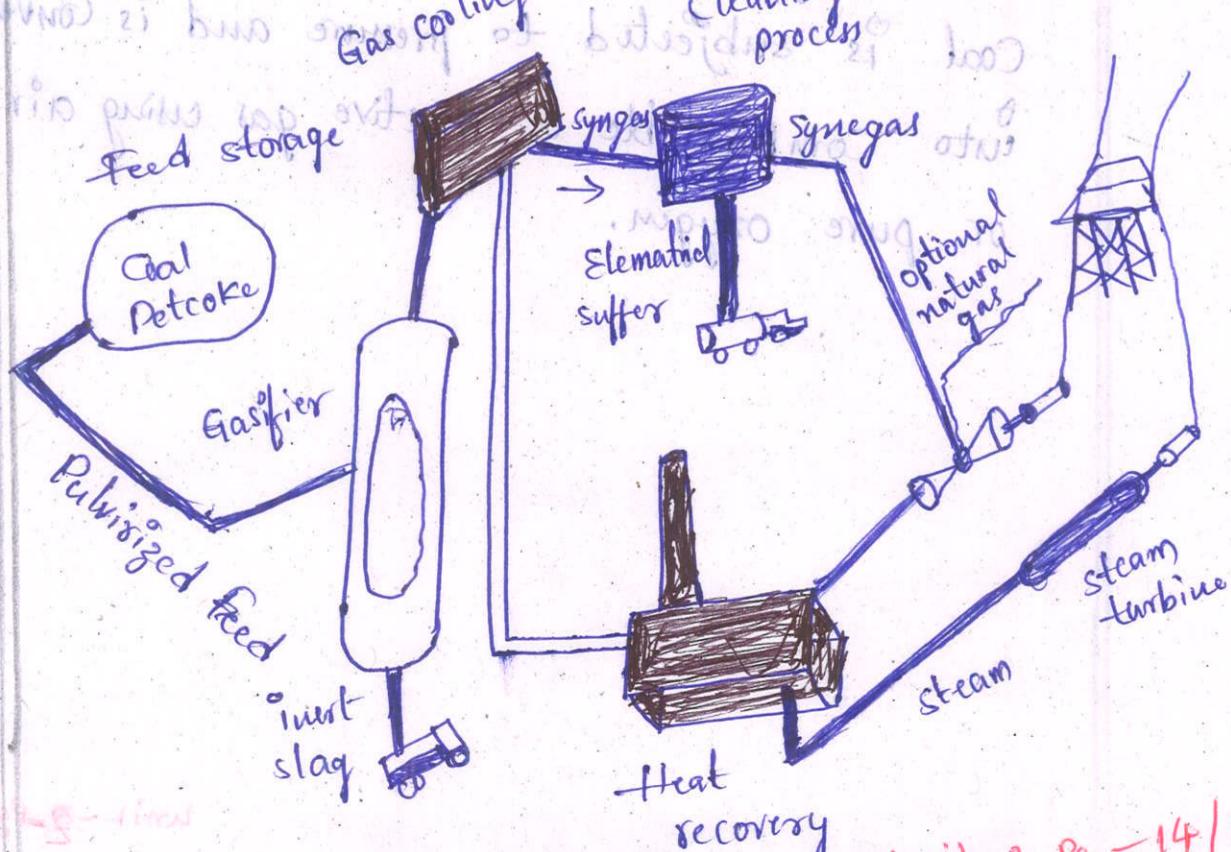
* In IGCC power plants, the coal is not burnt in a conventional steam power plant, but is initially dried and supplied to a gasifier, in which high temperatures prevail. Here, the dried coal is subjected to pressure and is converted into combustible or reactive gas using air or pure oxygen.



How it works

* IGCC uses a coal gasification system to convert coal into a synthetic gas and produce steam.
the hot syngas is processed to remove sulfur compounds, mercury and particulate matter above, before it is used to fuel a combustion turbine generator, which produces electricity. the heat in the exhaust gases from the combustion turbine is recovered to generate additional steam. this steam, along with that from the syngas process, then drives a steam turbine generator to produce additional electricity.

Lay out of IGCC power plant



* The plant includes :-

- * Coal preparation
- * Air separation
- * Coal gasification
- * Ash removal
- * Syngas cooling
- * Acid gas removal
- * Sulphur gas recovery

* Advantages:-

- * High combined cycle power plant efficiencies
- * Modular IGCC concepts to enable phased construction
- * Less use of water than conventional coal power plant
- * Easy separation of CO_2

* Draw back or disadvantages:-

- * High Capital cost
- * More components, more heat exchangers increase maintenance costs and outage times
- * The startup times of IGCC will be more than pulverized coal fired power plant due to the large number of sub systems. This makes the IGCC suitable only for load unit-~~289~~-1515 operation

the subject's study of a

continuing loss of

confidence in

existing law

and power to

protect us

from his

treacherous

and unprincipled

and unchristian

and unfriendly ways than those of right

and sharp and stinging words, nothing

but contempt

and derision, rebuking and rebuffing

and rebuffing

and rebuffing

and rebuffing

and rebuffing

and rebuffing, and more rebuffing, some

more rebuffing than rebuffing, still more

and rebuffing, and more rebuffing, still more