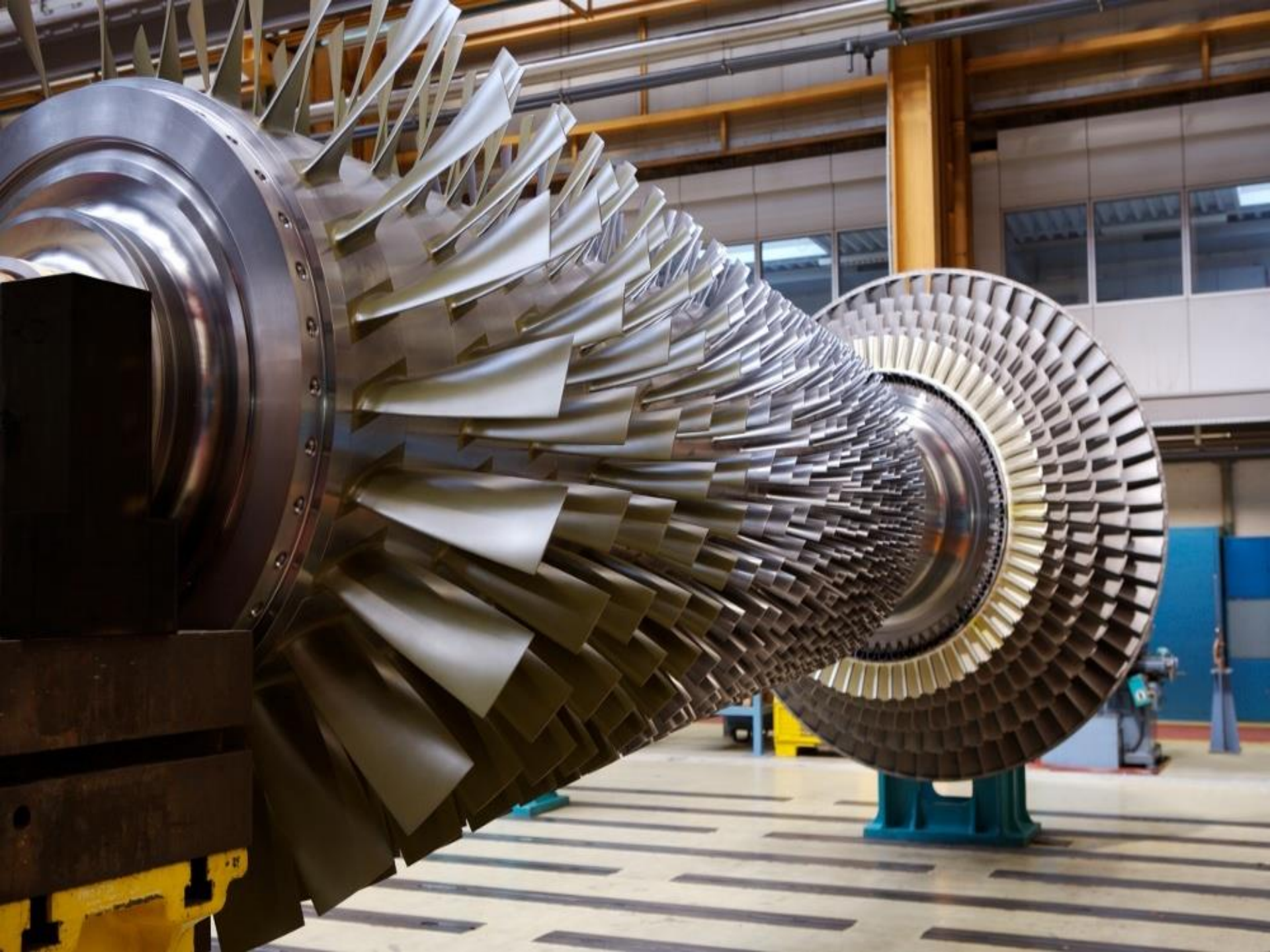
Gas Turbine Power Plant



Gas turbine power plant

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.

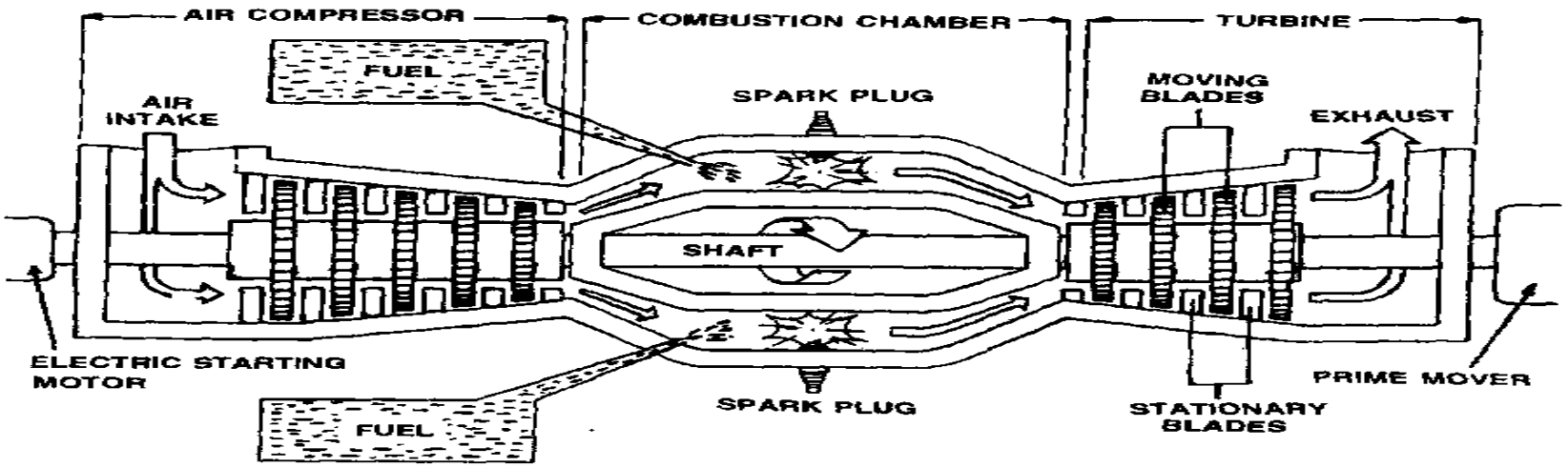
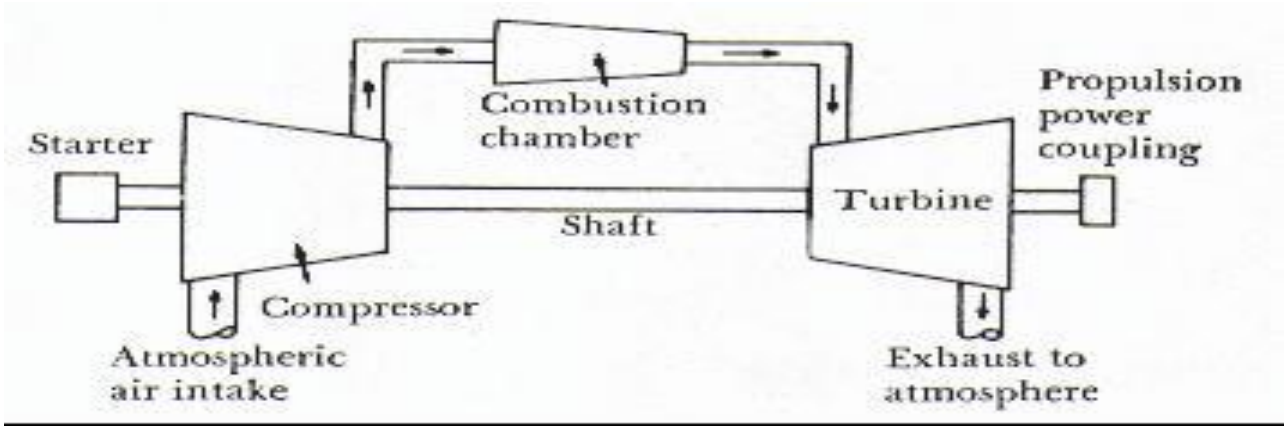
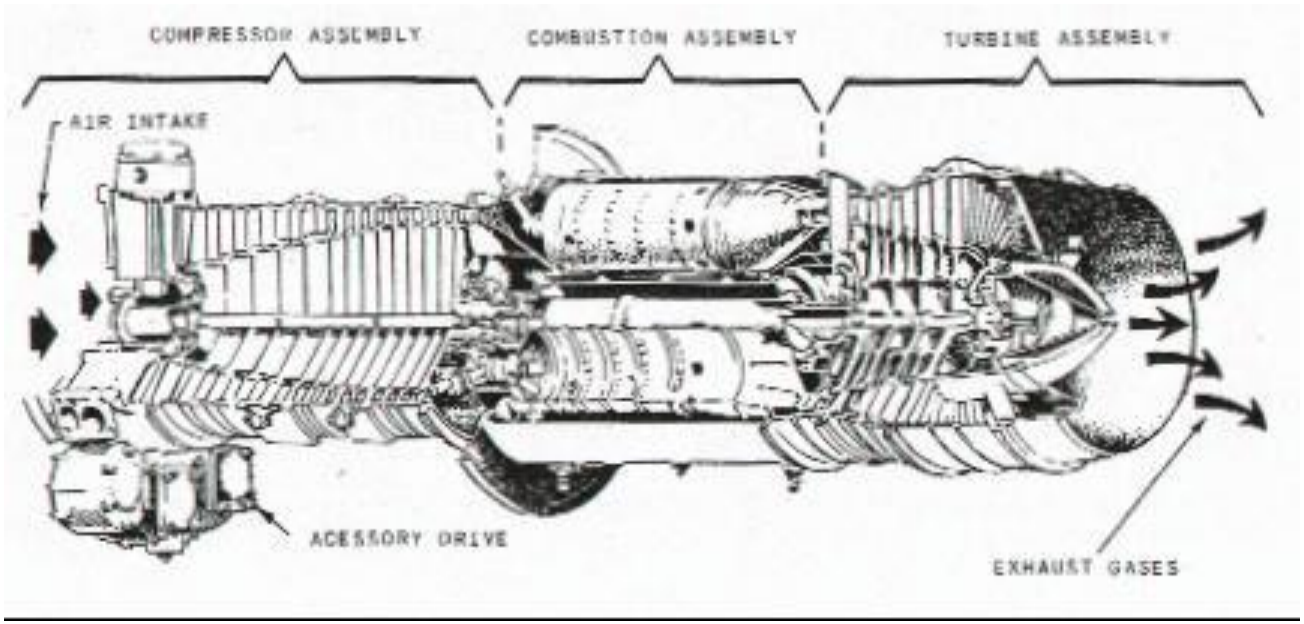


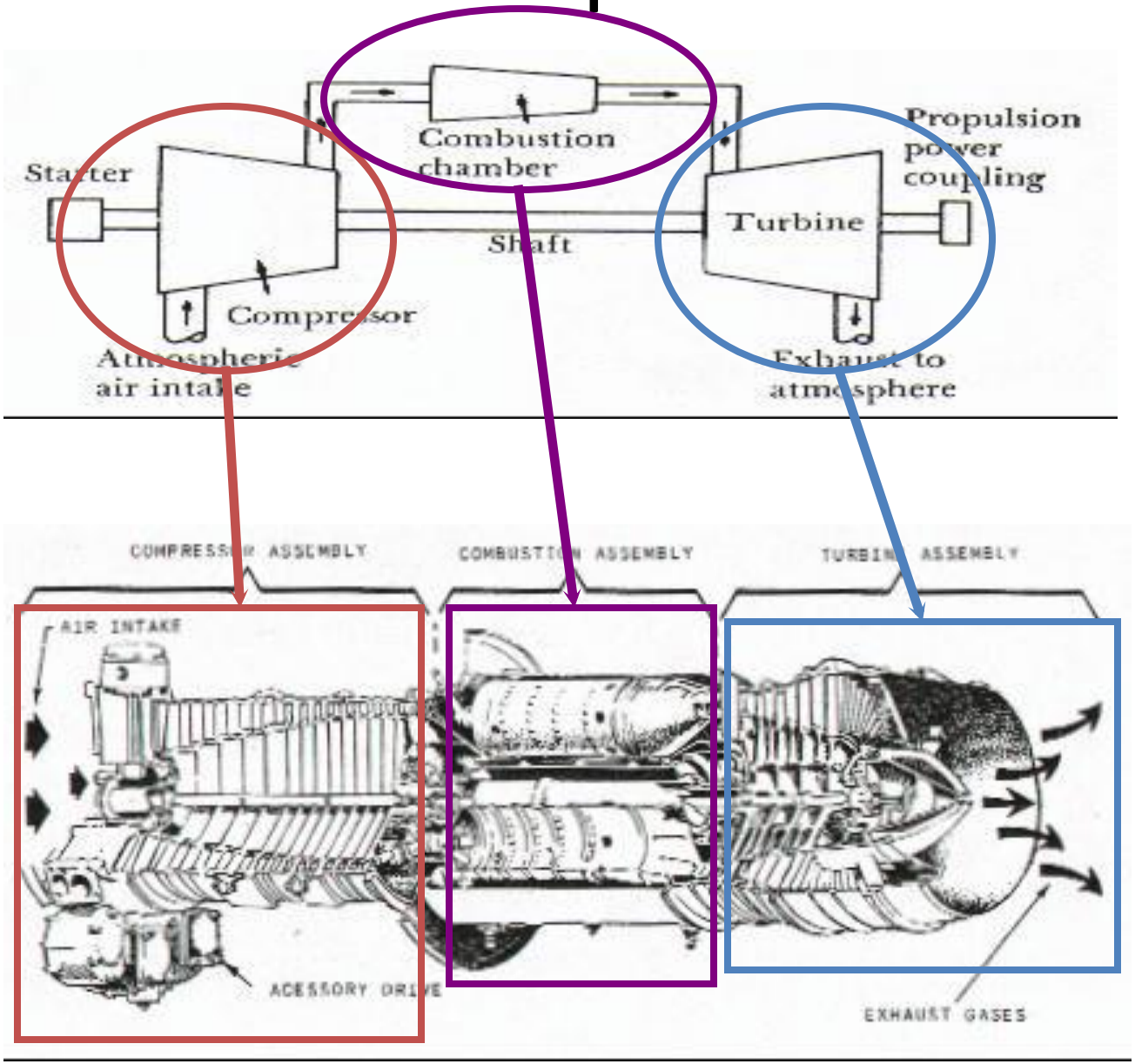
Fig. 2.28: HOW A GAS TURBINE SYSTEM WORKS

Basic Components





Basic Components



Energy Flow Diagram

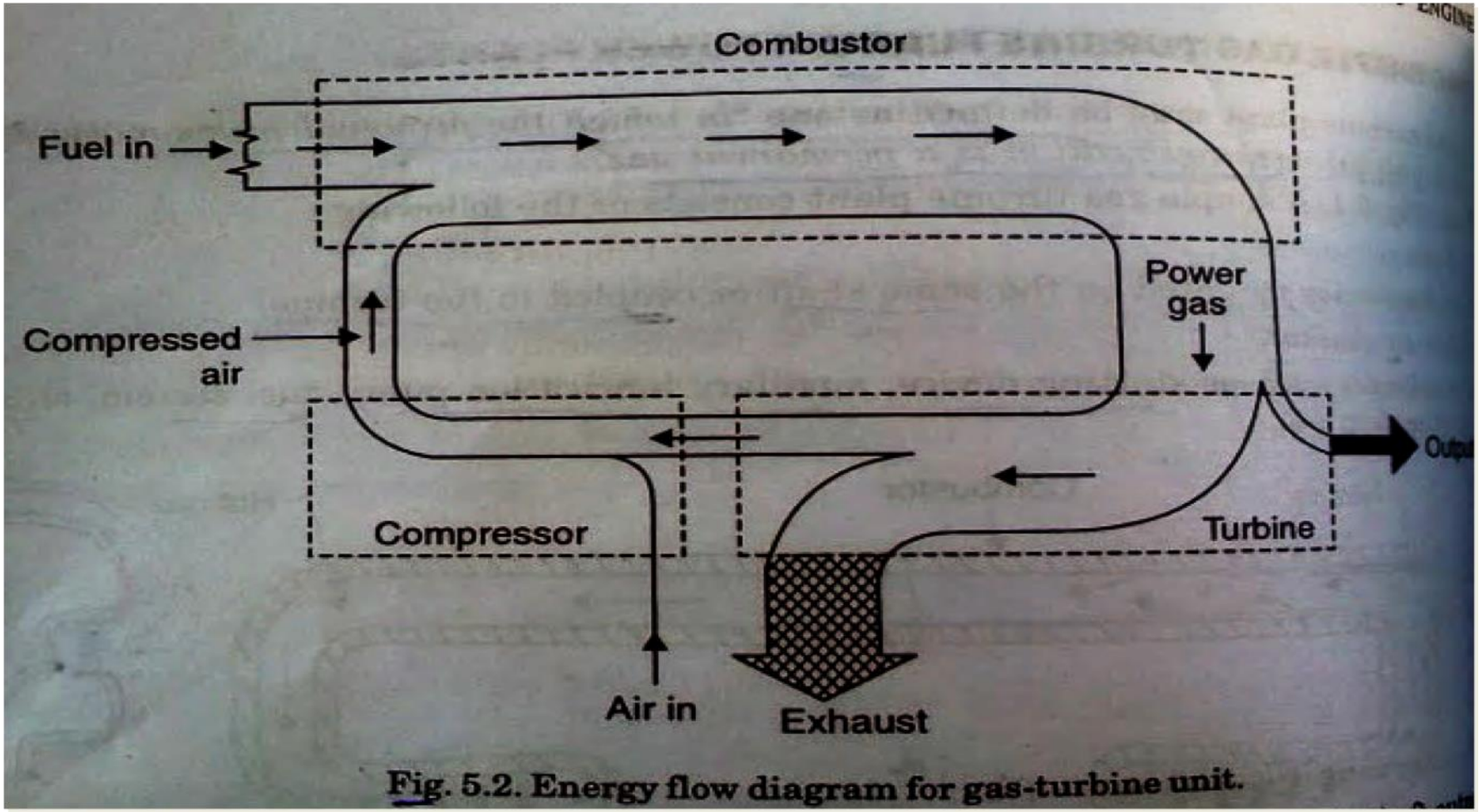


Fig. 5.2. Energy flow diagram for gas-turbine unit.

Gas turbine power plant

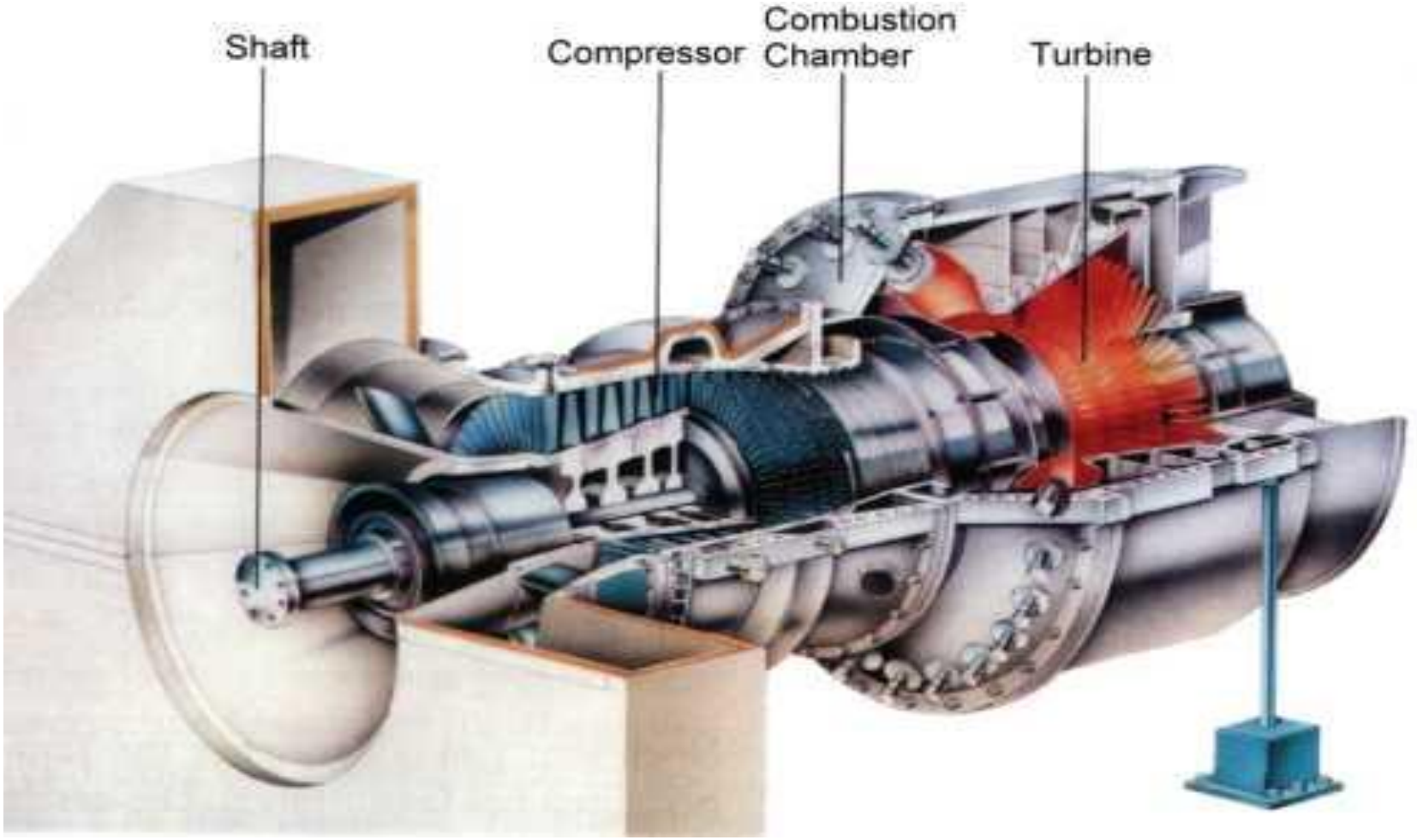
Description:

- Gas turbines burn fuels such as oil, nature gas and pulverized(powdered) coal.
- Gas turbines have three main parts:

i) Air compressor

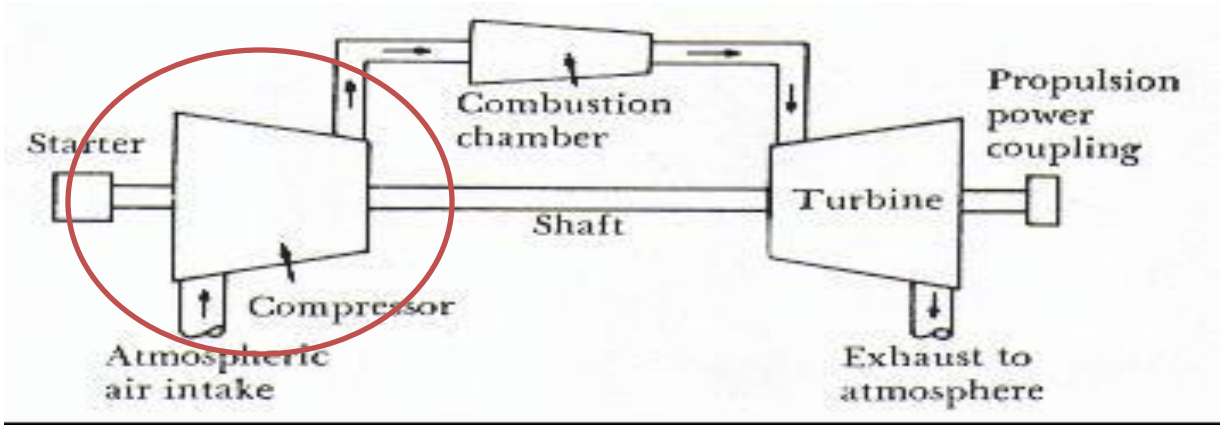
ii) Combustion chamber

iii) Turbine


Shaft
Compressor
Combustion Chamber
Turbine

Basic Components

- Compressor
  - Draws in air & compresses it
- Combustion Chamber
  - Fuel pumped in and ignited to burn with compressed air
- Turbine
  - Hot gases converted to work
  - Can drive compressor & external load



Basic Components

- Compressor
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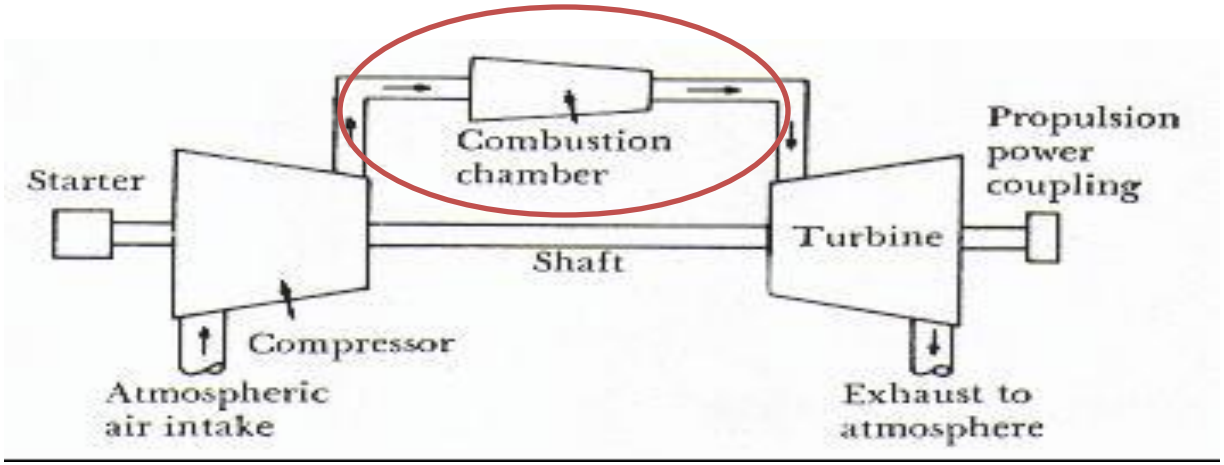

Basic Components

- Compressor
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- Combustion Chamber
  - Fuel pumped in and ignited to burn with compressed air
- Turbine
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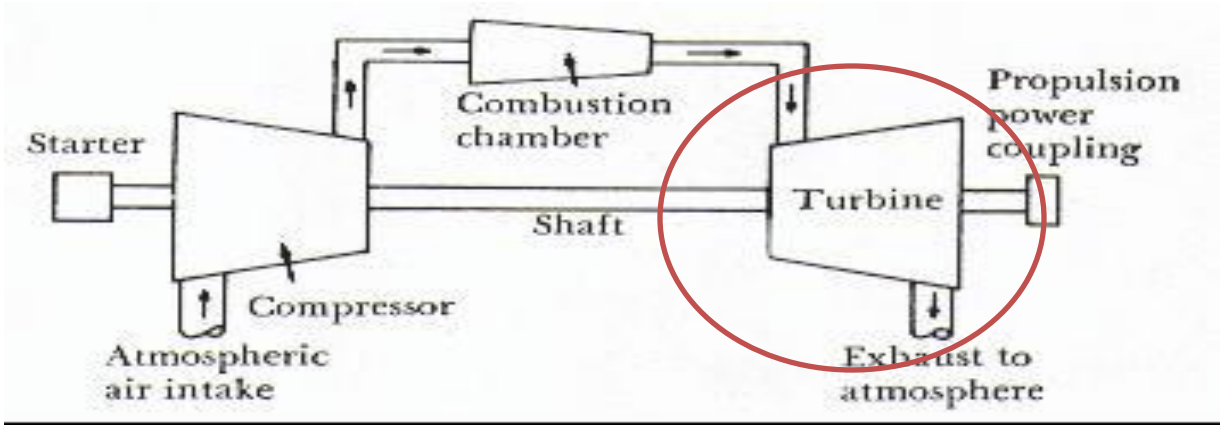
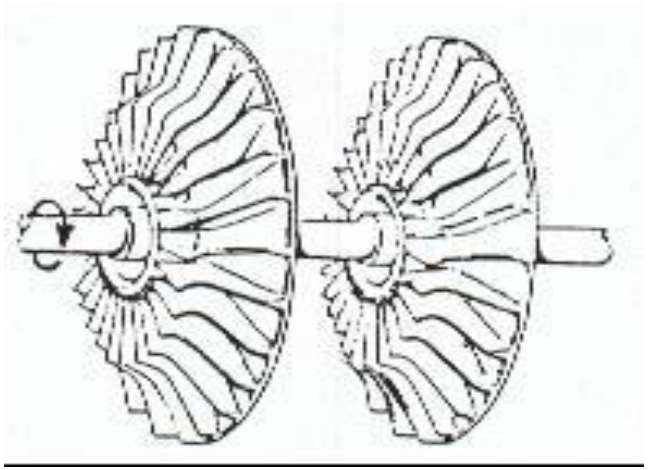


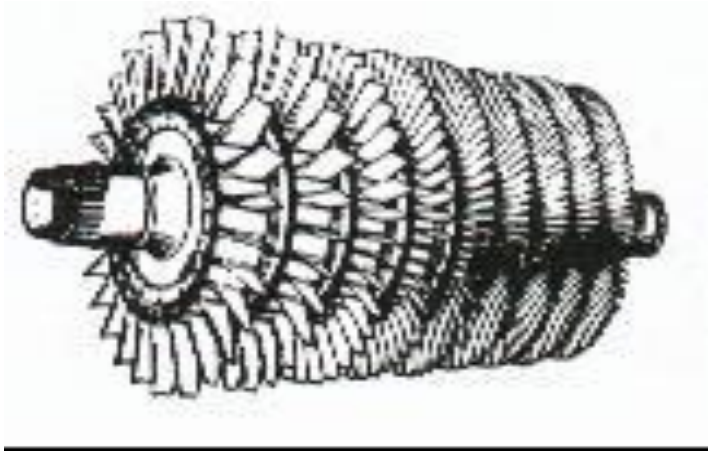
Compressor

- Supplies high pressure air for combustion process
- Compressor types
  - Radial/centrifugal flow compressor
  - Axial flow compressor

Compressor

- Radial/centrifugal flow
  - Adv: simple design, good for low compression ratios (5:1)
  - Disadvantage: Difficult to stage, less efficient
- Axial flow
  - Good for high compression ratios (20:1) - Most commonly used





Compressor

- Controlling Load on Compressor
  - To ensure maximum efficiency and allow for flexibility, compressor can be split into HP & LP sections
  - Vane control: inlet vanes/nozzle angles can be varied to control air flow
- Compressor Stall
  - Interruption of air flow due to turbulence

Use of Compressed Air

- Primary Air (30%)
  - Passes directly to combustor for combustion process
- Secondary Air (65%)
  - Passes through holes in perforated inner shell & mixes with combustion gases
- Film Cooling Air (5%)
  - Insulates/cools turbine blades

Combustion Chambers

- Where air & fuel are mixed, ignited, and burned
- Spark plugs used to ignite fuel
- Types
  - Can: for small, centrifugal compressors
  - Annular: for larger, axial compressors (LM 2500)
  - Can-annular: for really large turbines

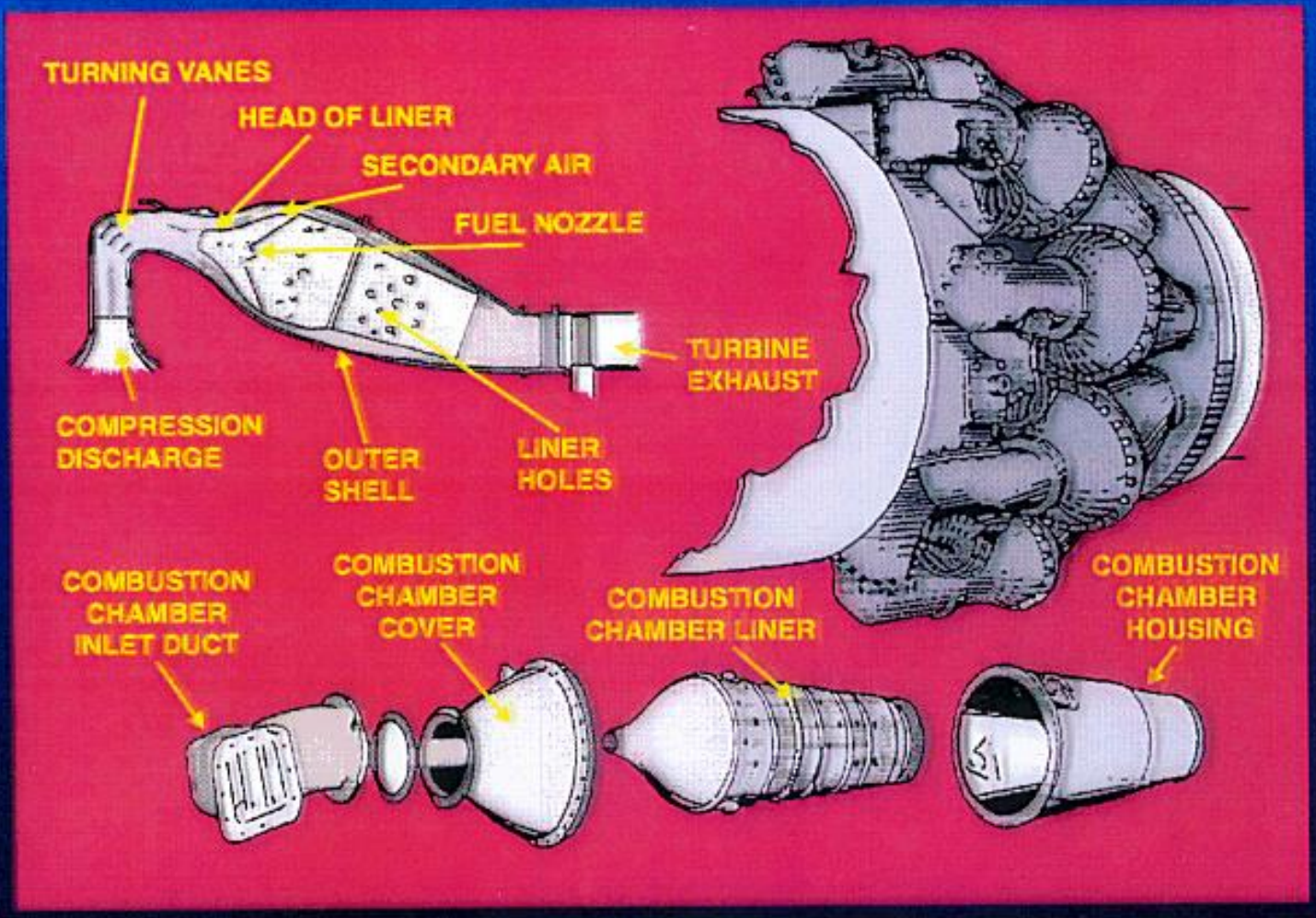


Figure 16-10

CAN-TYPE COMBUSTION CHAMBER

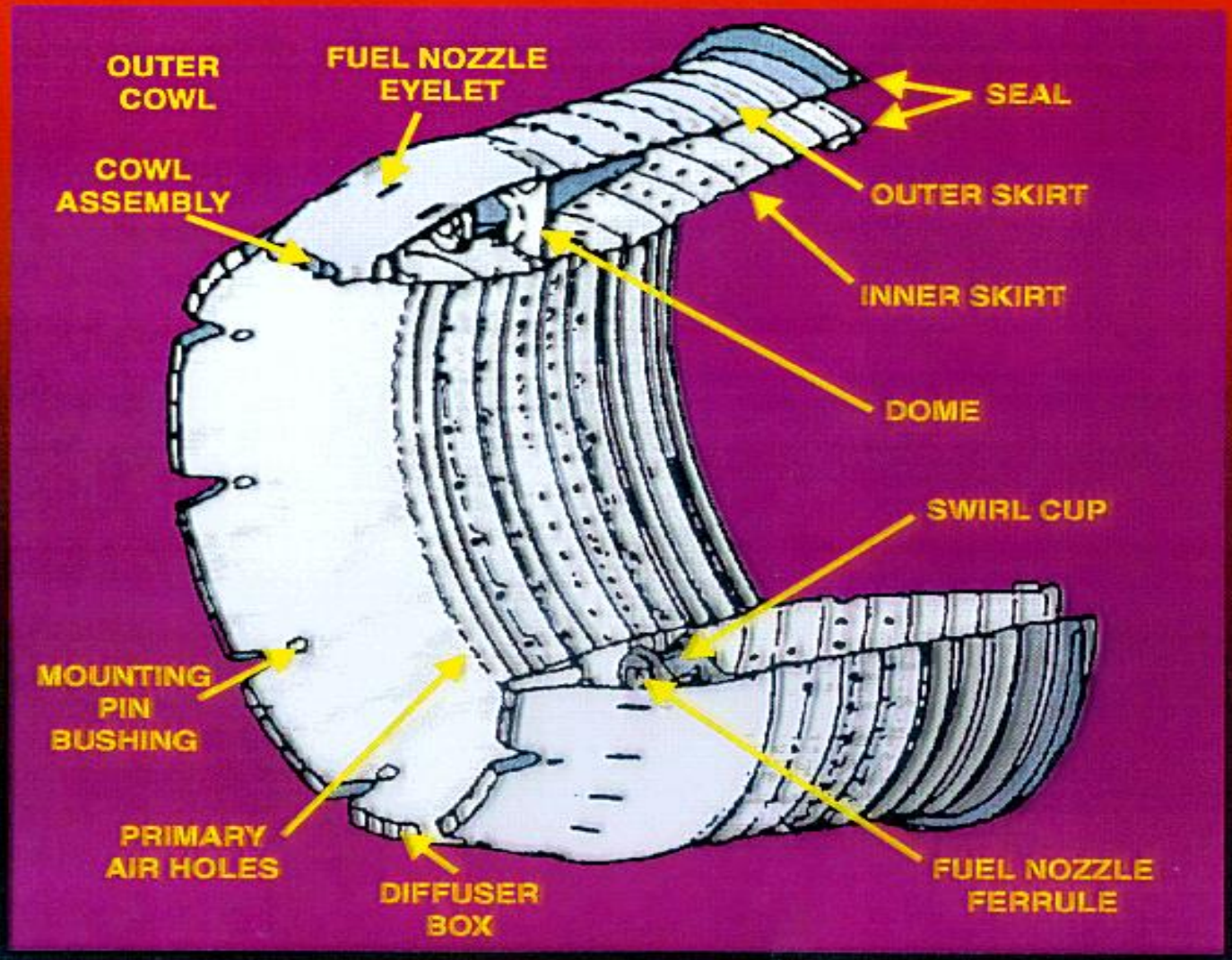


Figure 16-11

ANNULAR-TYPE COMBUSTION CHAMBER

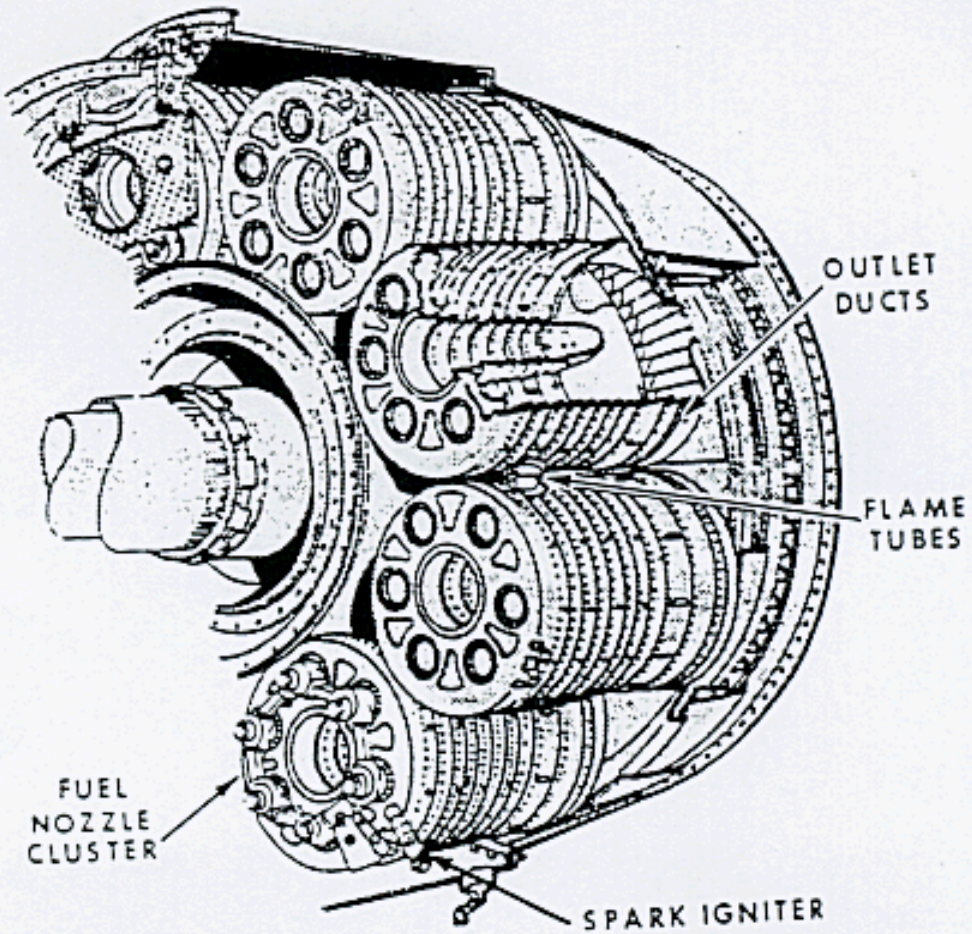


Figure 16-12.—Can-annual-type combustion chamber.

Turbines

- Consists of one or more stages designed to develop rotational energy
- Uses sets of nozzles & blades

Gas turbine power plant…

Applications of gas turbine:

- drive pumps, compressors and high speed cars.
- aircraft and ships.
- Power generation (used for peak load and as stand-by unit).

OPEN CYCLE GAS TURBINE POWER PLANTAND ITS CHARACTERISTICS

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 the 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 re-circulated), causing the cycle to be classified as an **open cycle**

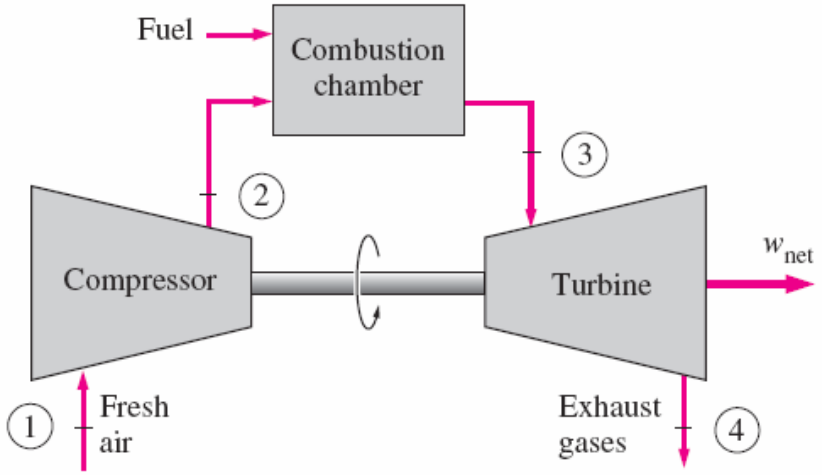


FIGURE 9–29

An open-cycle gas-turbine engine.

CLOSED CYCLE GAS TURBINE POWER PLANT AND ITS CHARACTERISTICS

- The compression and expansion processes remain the same, but the combustion process is replaced by a **constant-pressure heat addition** process from an external source.
- The exhaust process is replaced by a **constant-pressure heat rejection** process to the ambient air.

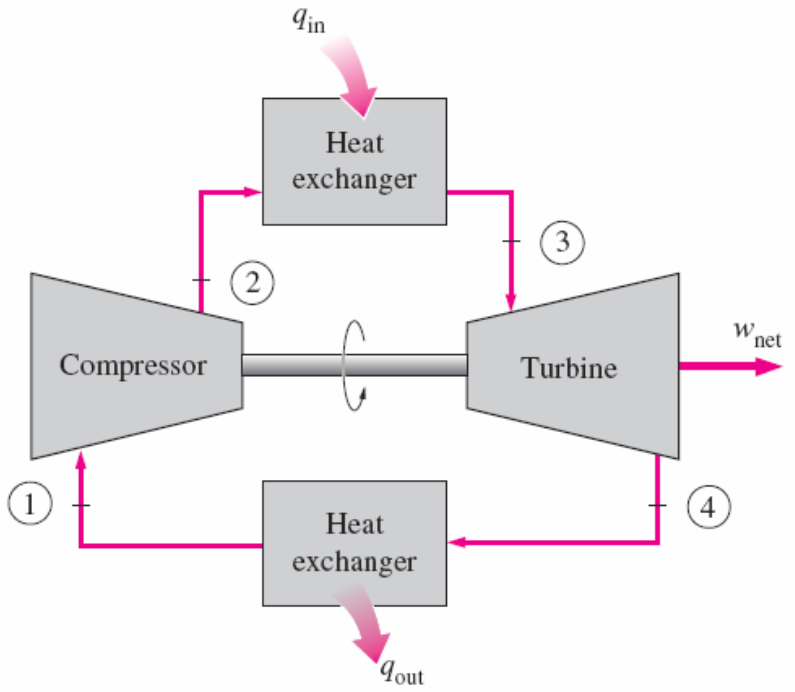
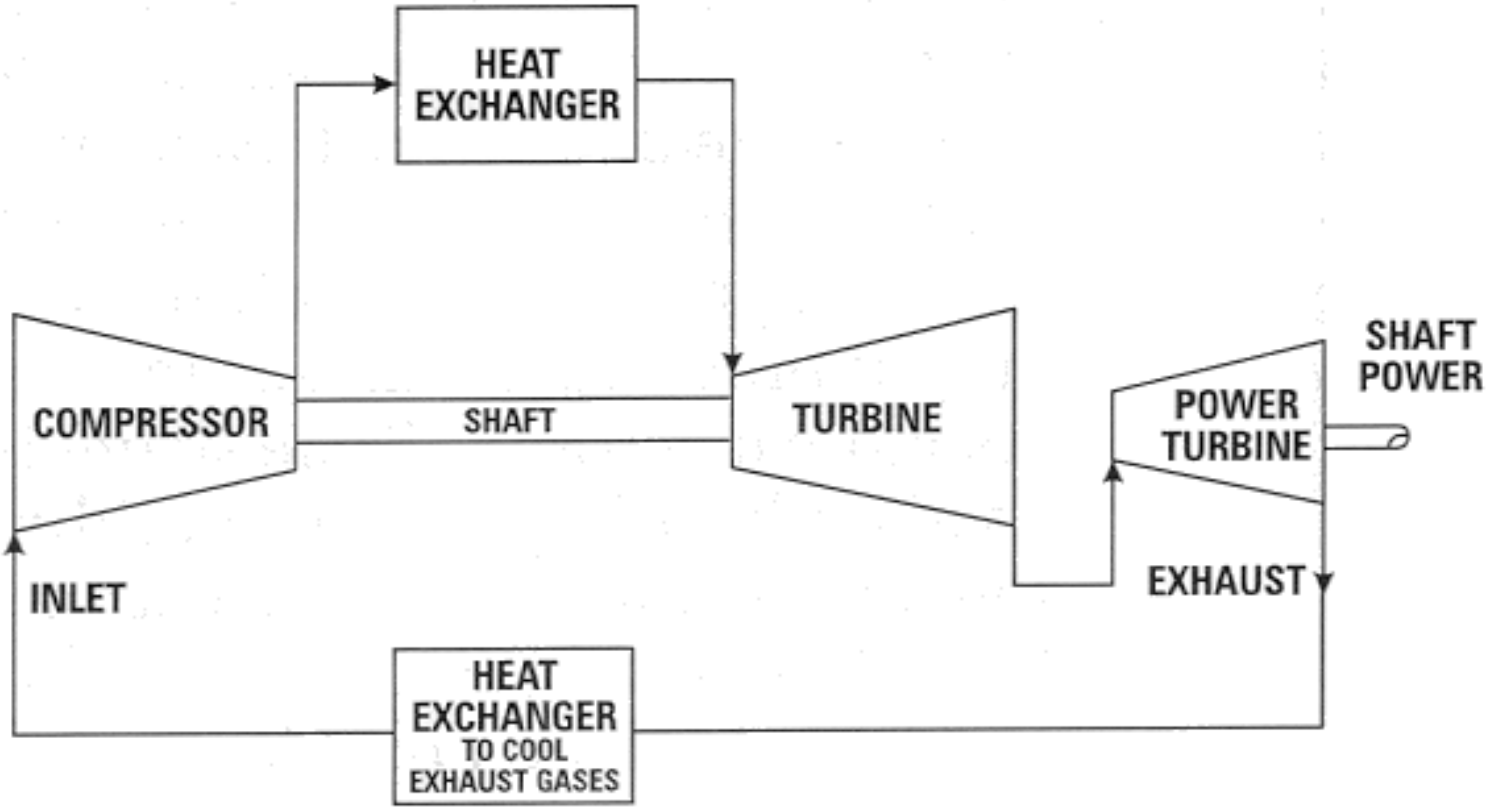


FIGURE 9–30
A closed-cycle gas-turbine engine.

Closed cycle gas turbine power plant



Advantages of gas turbine power plant

- Storage of fuel requires less area and handling is easy.
- The cost of maintenance is less.
- It is simple in construction. There is no need for boiler, condenser and other accessories as in the case of steam power plants.
- Cheaper fuel such as kerosene , paraffin, benzene and powdered coal can be used which are cheaper than petrol and diesel.
- Gas turbine plants can be used in water scarcity areas.
- Less pollution and less water is required.

Disadvantages of gas turbine power plant

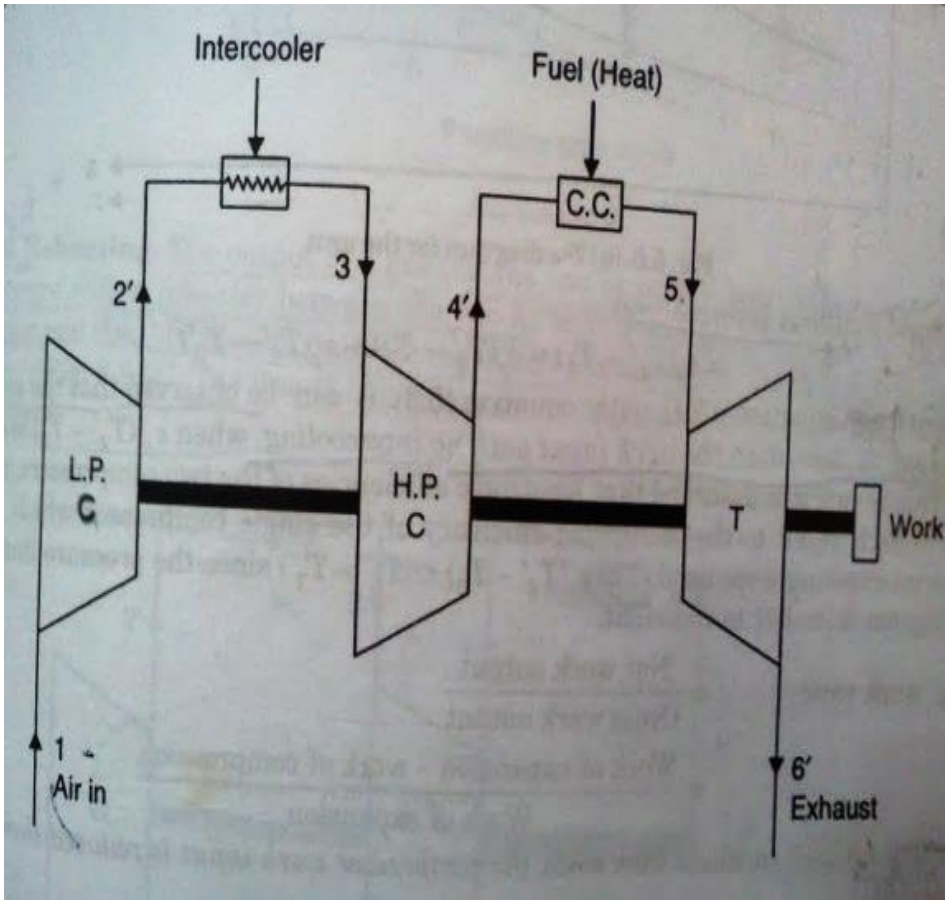
- 66% of the power developed is used to drive the compressor. Therefore the gas turbine unit has a low thermal efficiency.
- The running speed of gas turbine is in the range of (40,000 to 100,000 rpm) and the operating temperature is as high as 1100 – 1260^0C. For this reason special metals and alloys have to be used for the various parts of the turbine.
- High frequency noise from the compressor is objectionable.

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

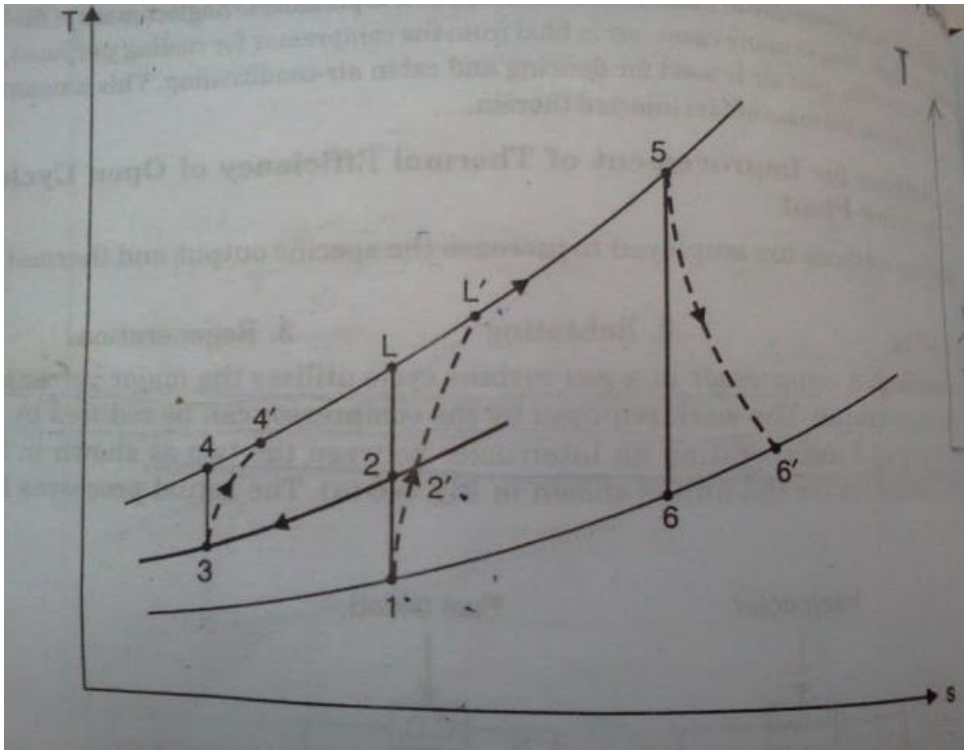
1. Intercooling
2. Reheating
3. Regeneration

Intercooling

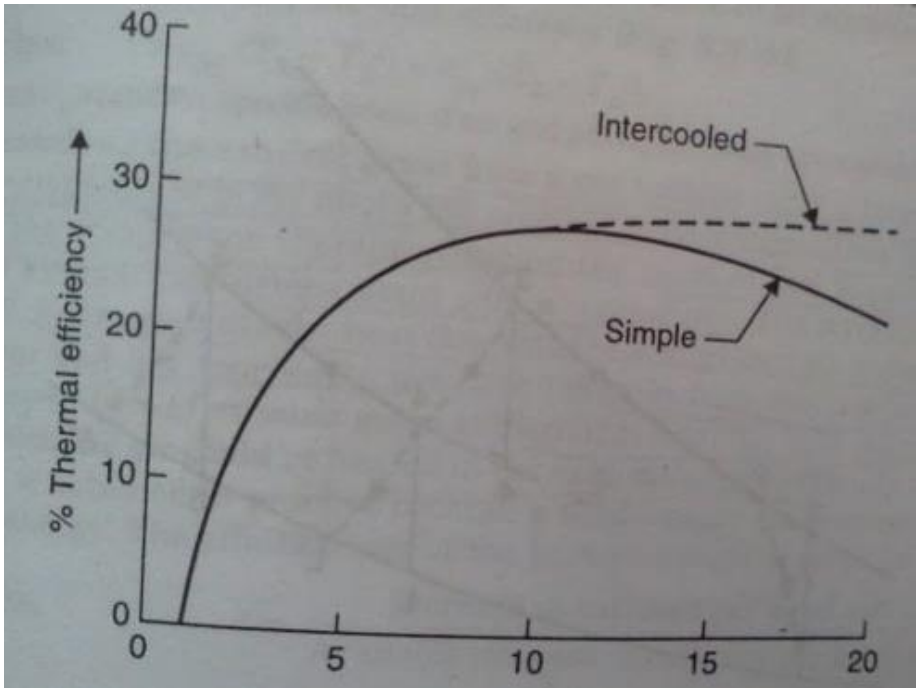
- A compressor utilizes the major percentage of power developed by the gas turbine. The work required by the compressor can be reduced by compressing the air in two stages and incorporation a intercooler between the two.



- 1-2’: LP compression
- 2’-3: Intercooling
- 3-4’: H.P. compression
- 4’-5: C.C. Combustion chamber(heating)
- 5-6’: T(Turbine) - Expansion

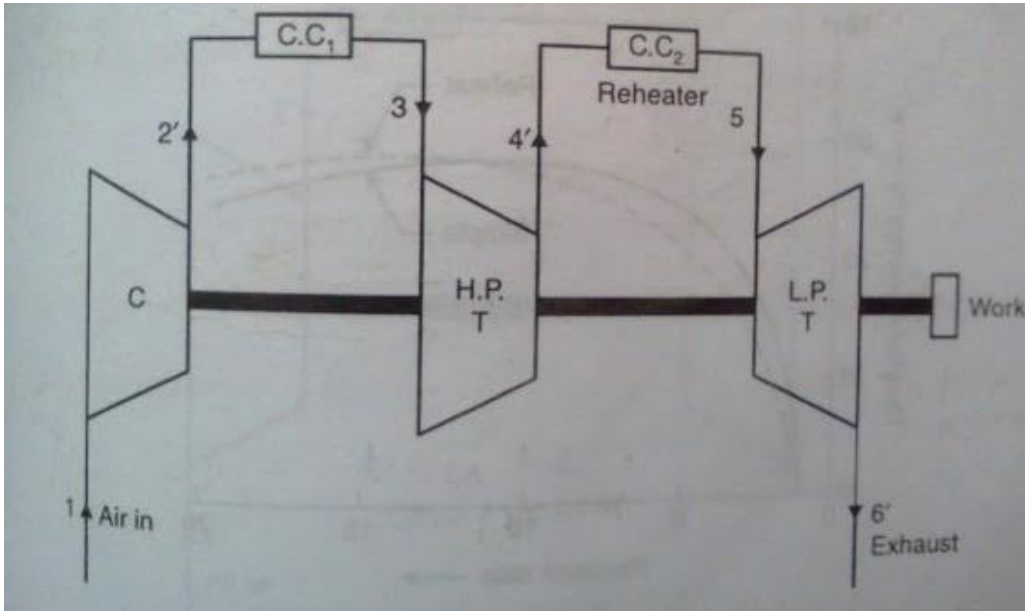


- Work Ratio is increased
- Thermal efficiency decreases but it increases at high pressure ratio.



Reheating

- The output of gas turbine can be improved by expanding the gasses in two stages with a reheater between the two.
- The H.P. turbine drives the compressor and the LP turbine provides useful power output.



T-s diagram for closed loop cycle turbine

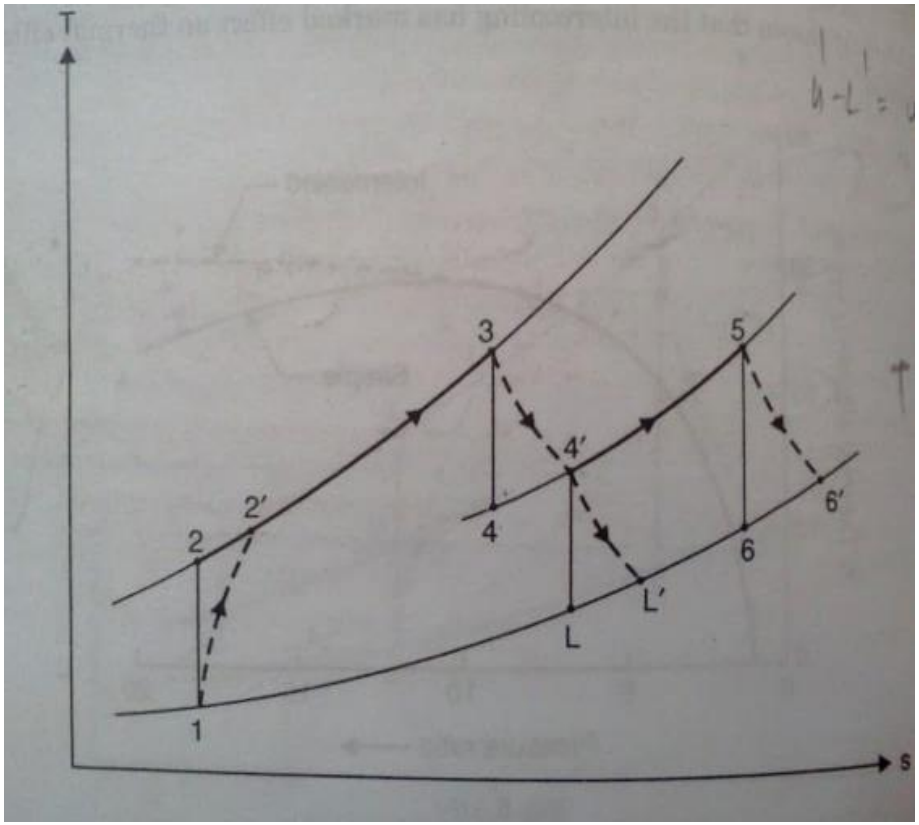
1-2’: Compression

2’-3: C.C (heating)

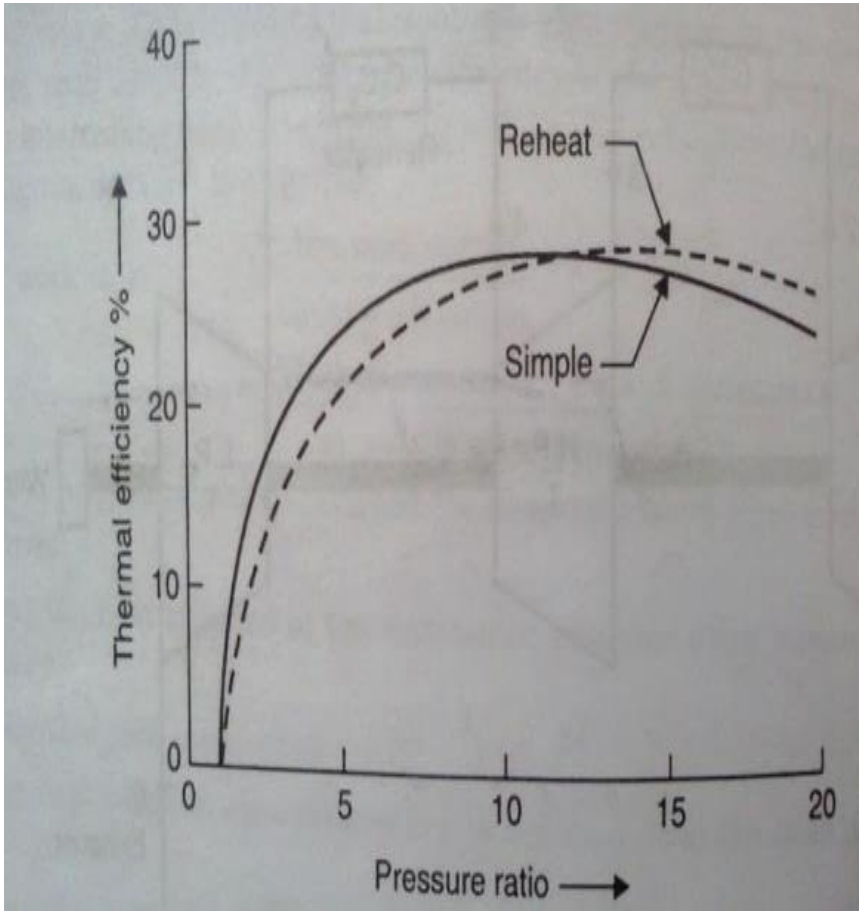
3’-4’: Turbine(Expansion)

4’-5: Reheater(heating)

5-6’: Turbine(Expansion)

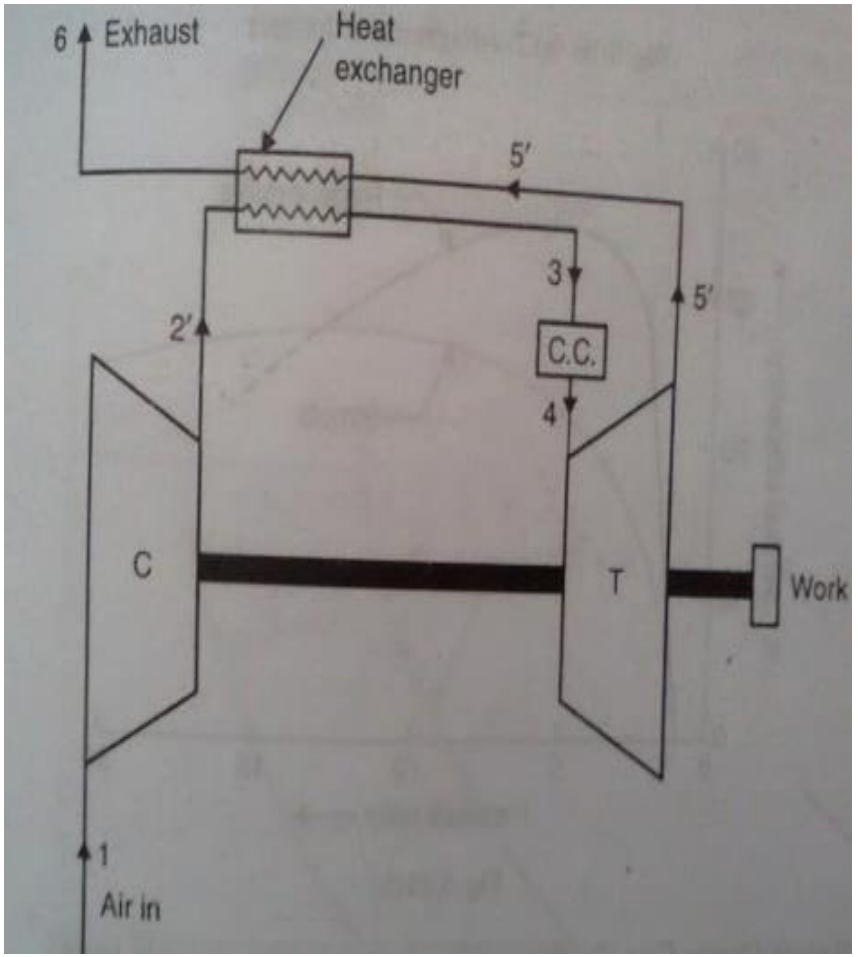


- Net Work output increases.
- Thermal Efficiency Decreases.

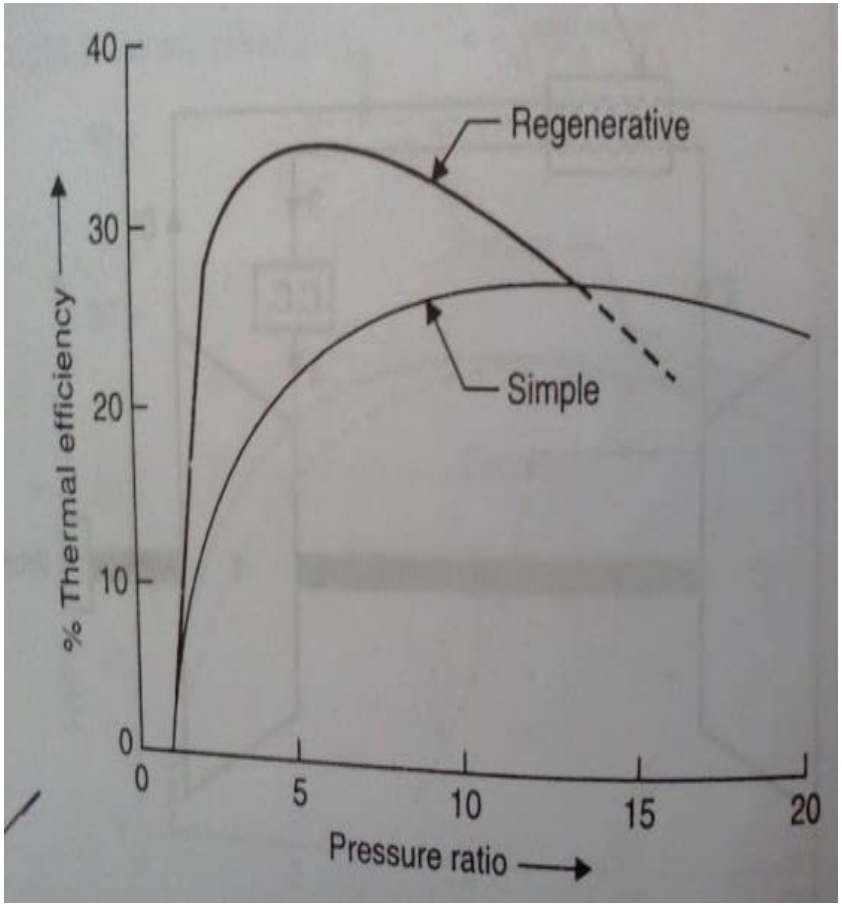


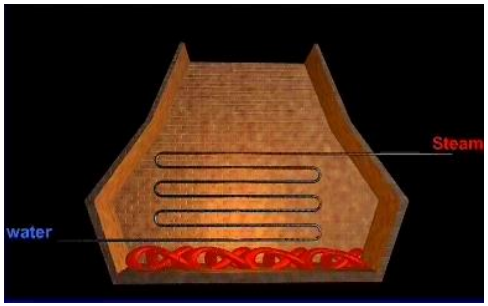
Regeneration

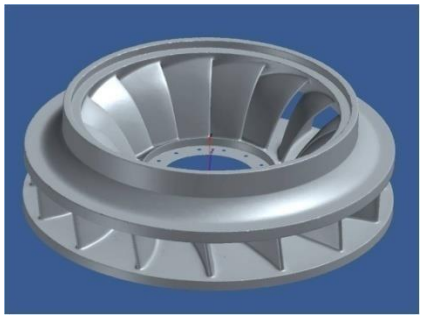
- The exhaust gasses from the turbine carry a large quantity of heat with them since their temperature is far above the ambient temperature.
- They can be used to heat air coming from the compressor there by reducing the mass of fuel supplied in the combustion chamber.

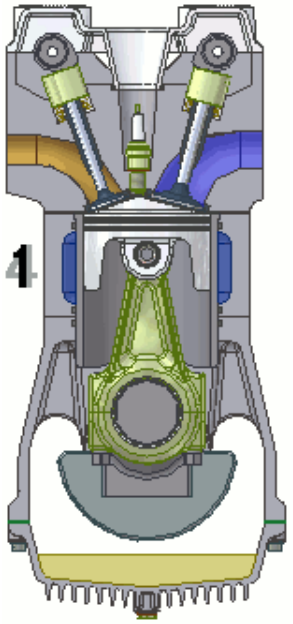


- Regenerative Cycle has more efficiency than simple cycle at lower pressure ratio.
- Above certain pressure ratio limit, the efficiency of cycle drops since in that case regenerator will cool the compressed sir instead of heating it




Steam
water

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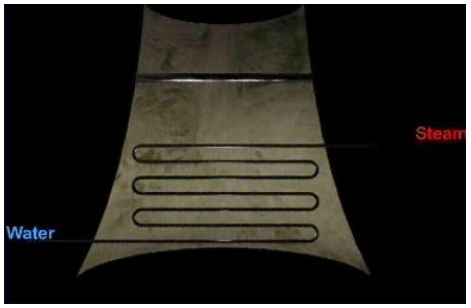
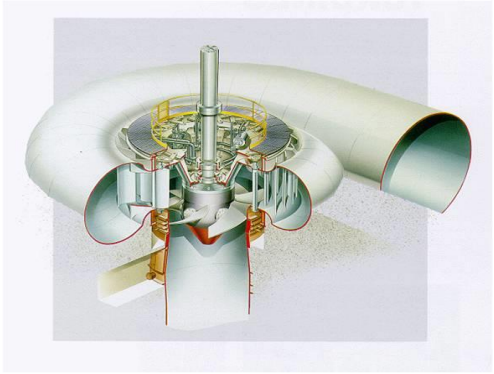
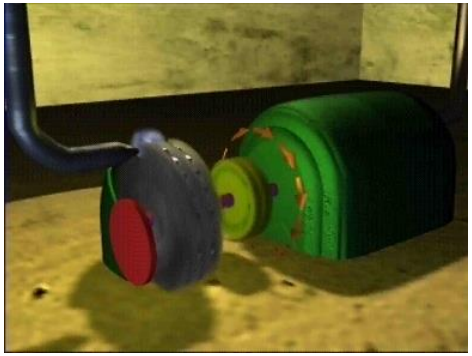
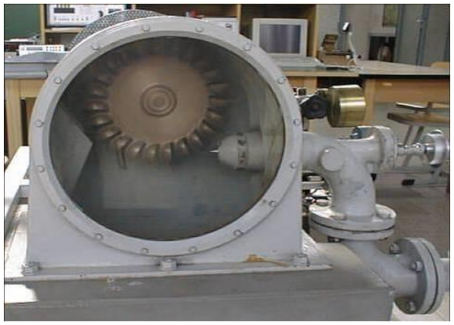

Steam
Water





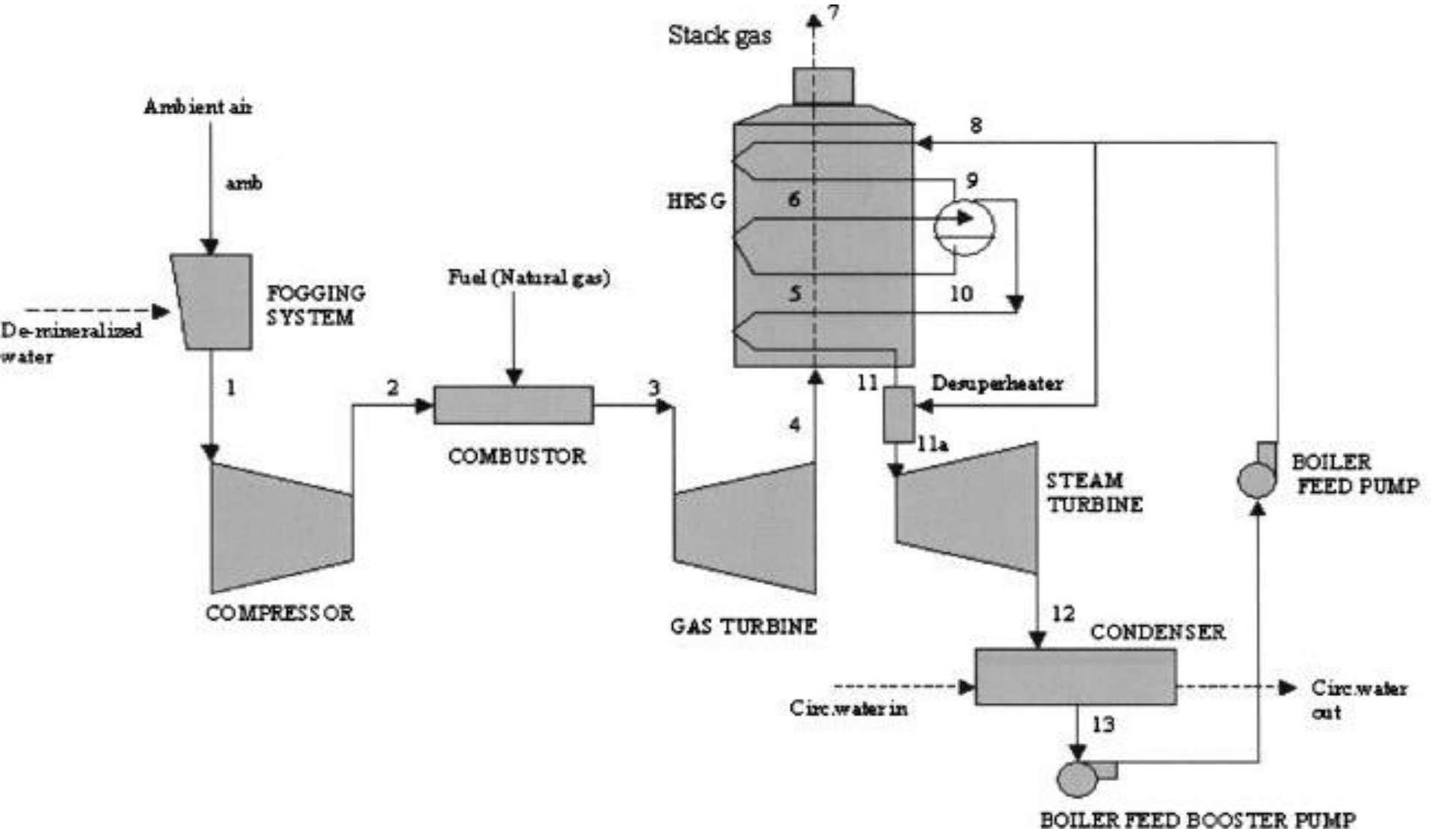


COMBINED POWER CYCLES

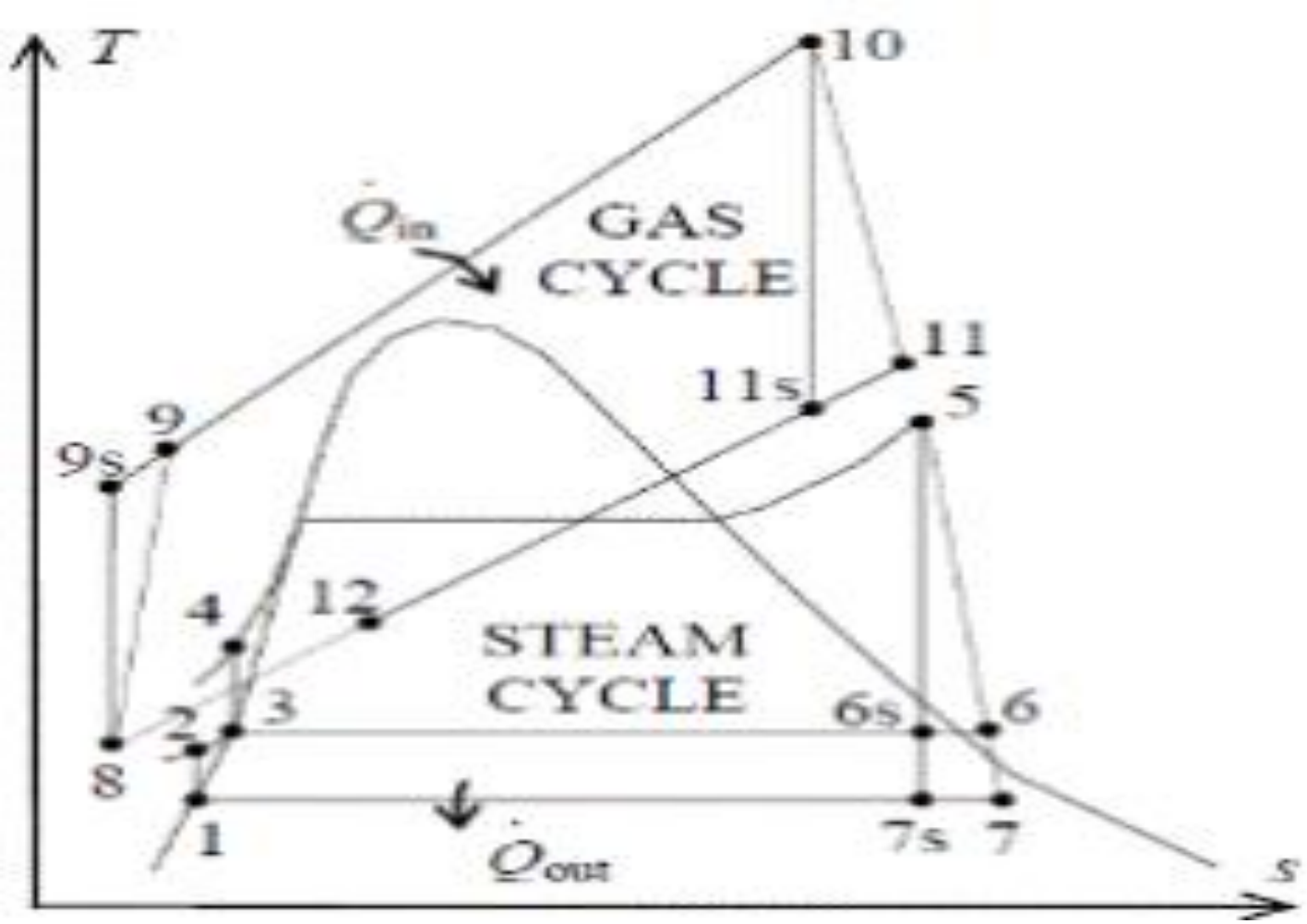
TYPES

- Gas Turbine-Steam Turbine Power Plant
- MHD-Thermionic Steam Power Plant
- Thermo Electric-Steam Power Plant
- MHD-Steam Power Plant
- Nuclear-Steam Combined Power Plant
- MHD-Gas Turbine Power Plant

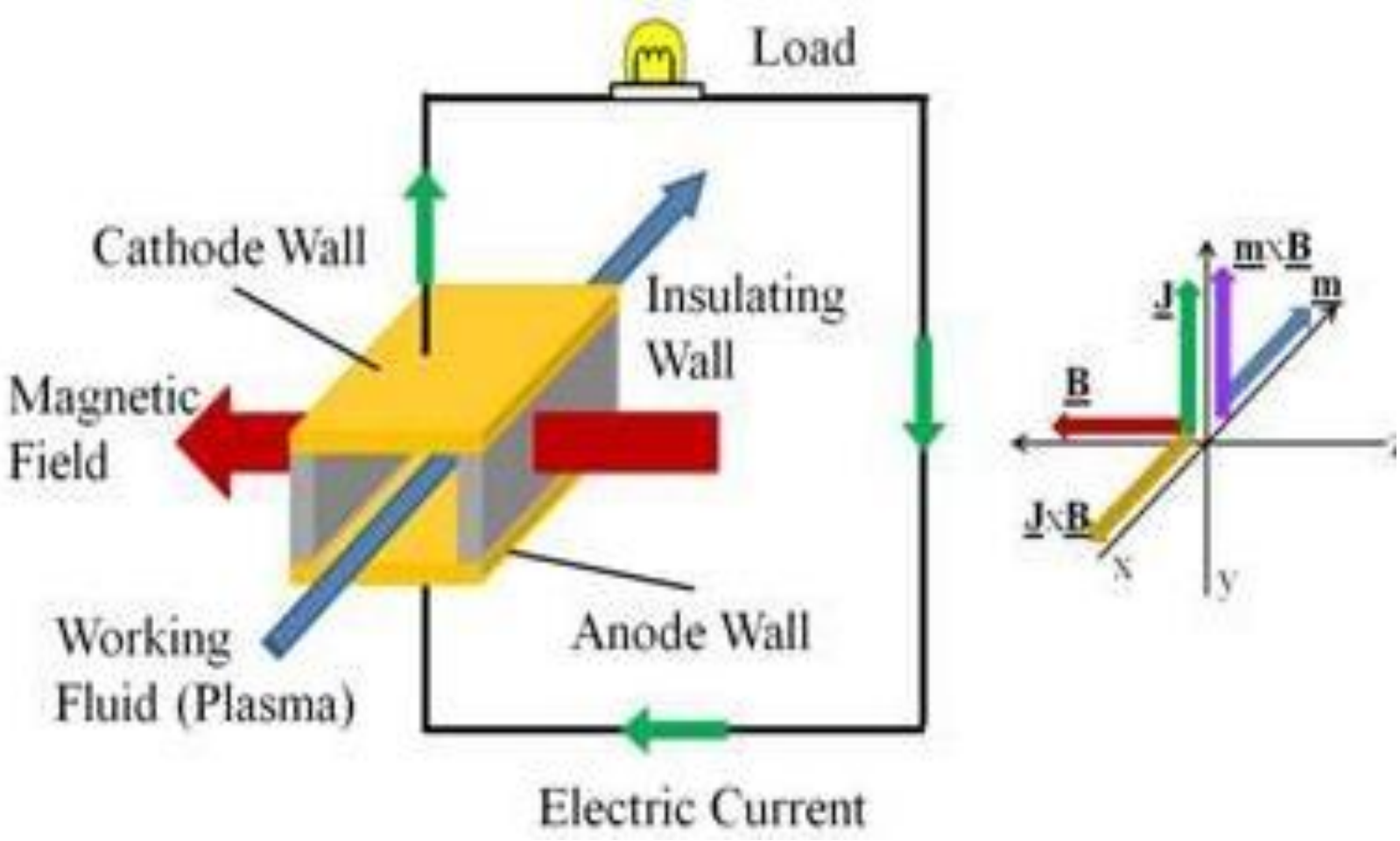
GAS TURBINE-STEAM TURBINE POWER PLANT



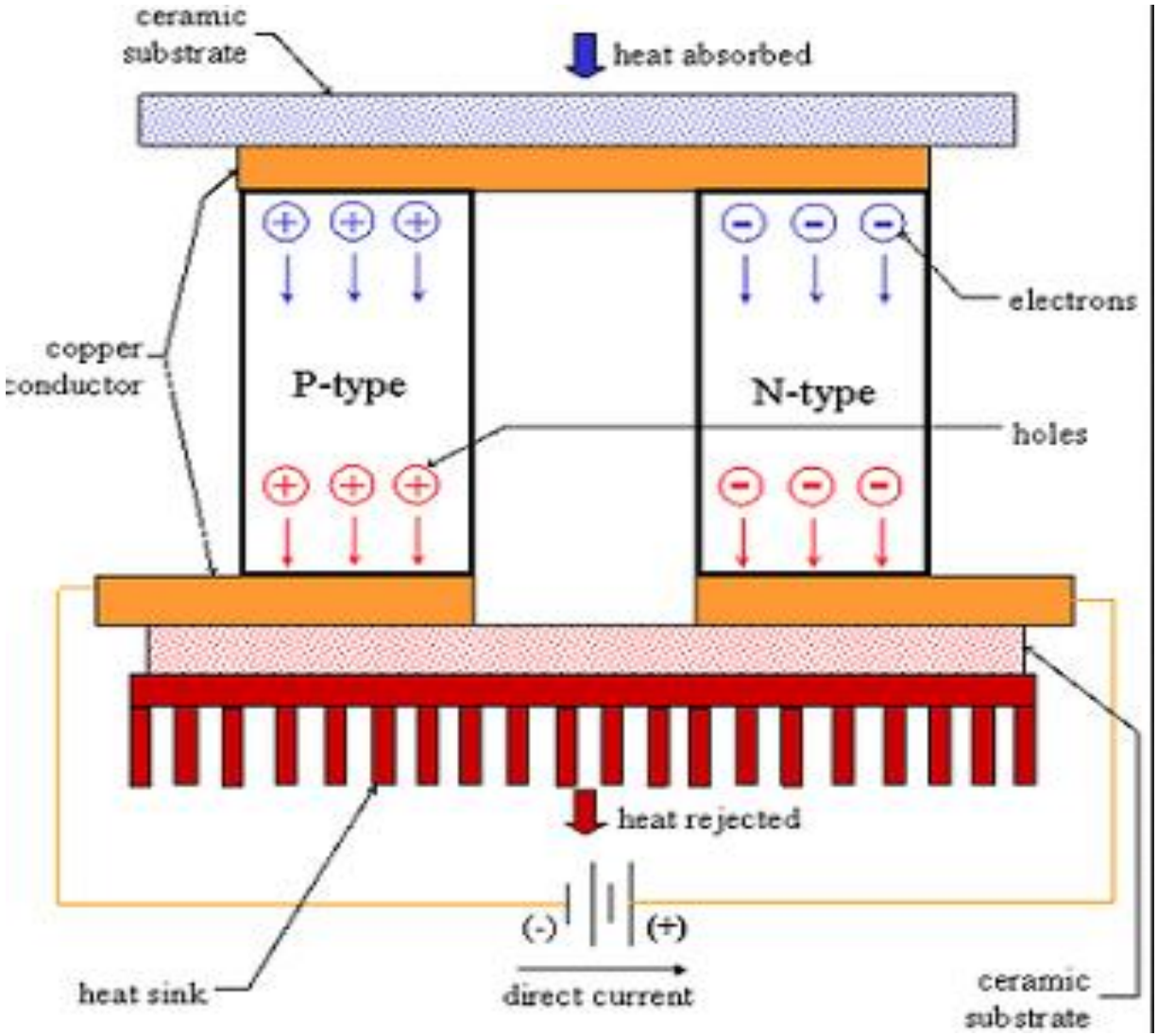
GAS TURBINE-STEAM TURBINE POWER PLANT



MHD-THERMIONIC STEAM POWER PLANT



THERMO ELECTRIC-STEAM POWER PLANT



Combined Cycle Power Plant

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 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***.


An Overview of
Combined Cycle Power Plant

Inner Workings of a Combined-Cycle 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.

Fig: A Combined Cycle Power Plant

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 drive shaft, where it is converted into additional electricity.

Advantages of Combined Cycle Power Plant

- 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

Disadvantages of Combined Cycle Power Plant

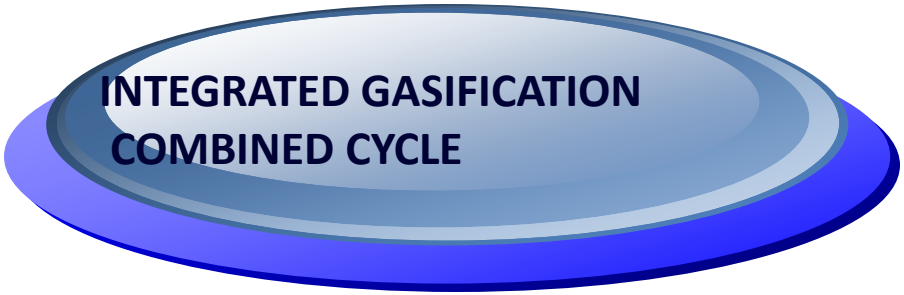
- Higher cost
- longer start-up
- less responsive to power demands
- shrill whining noise.

INTERGRATED GASIFICATION COMBINED CYCLE (IGCC)

Content

- Overview
- IGCC Process
- Future development
- Conclusions

Overview



GASIFICATION

PRODUCE SYNGAS

COMBINED CYCLE

POWER GENERATION

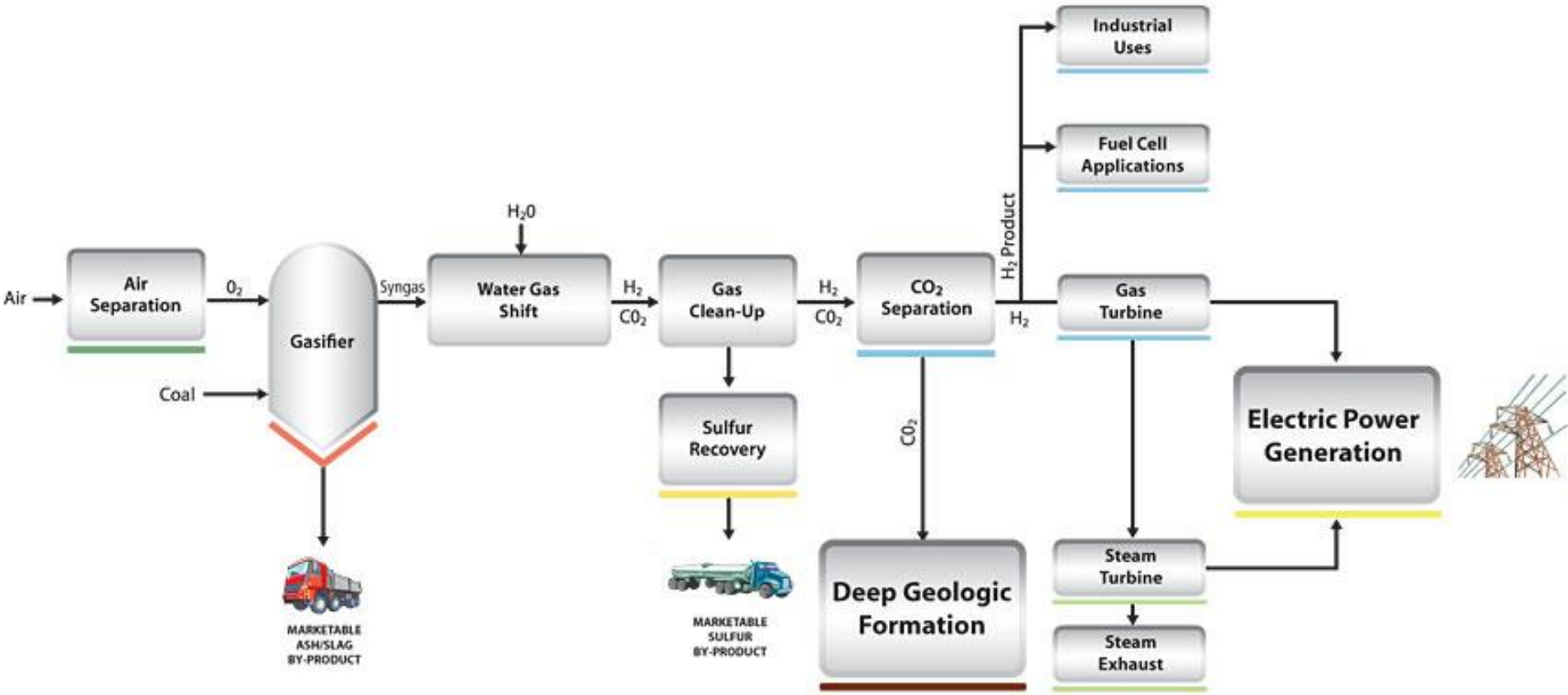
LOW EMISSION

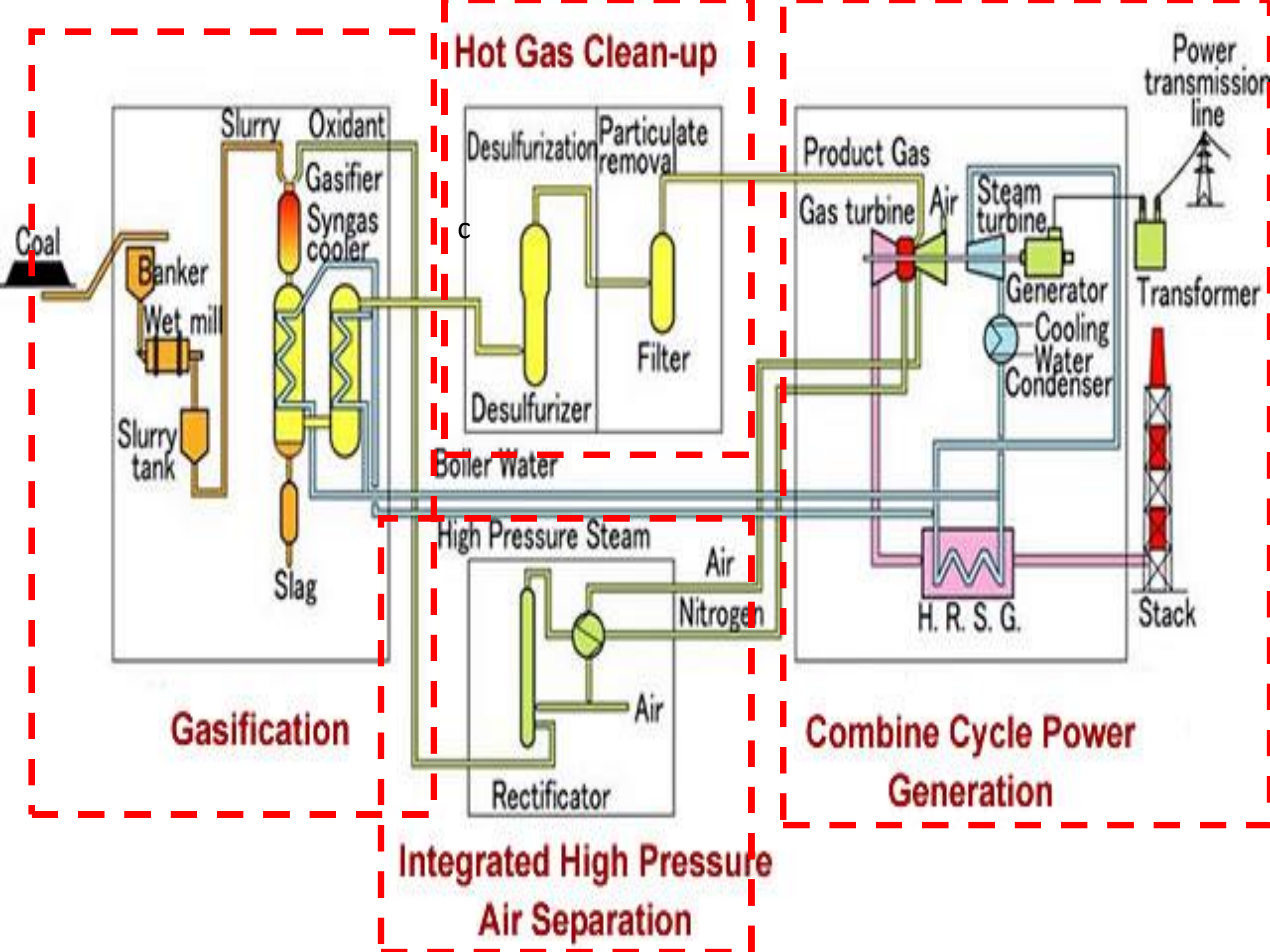
HIGH EFFICIENCY

IGCC PROCESS

FutureGen ALLIANCE

FutureGen's Integrated Technologies

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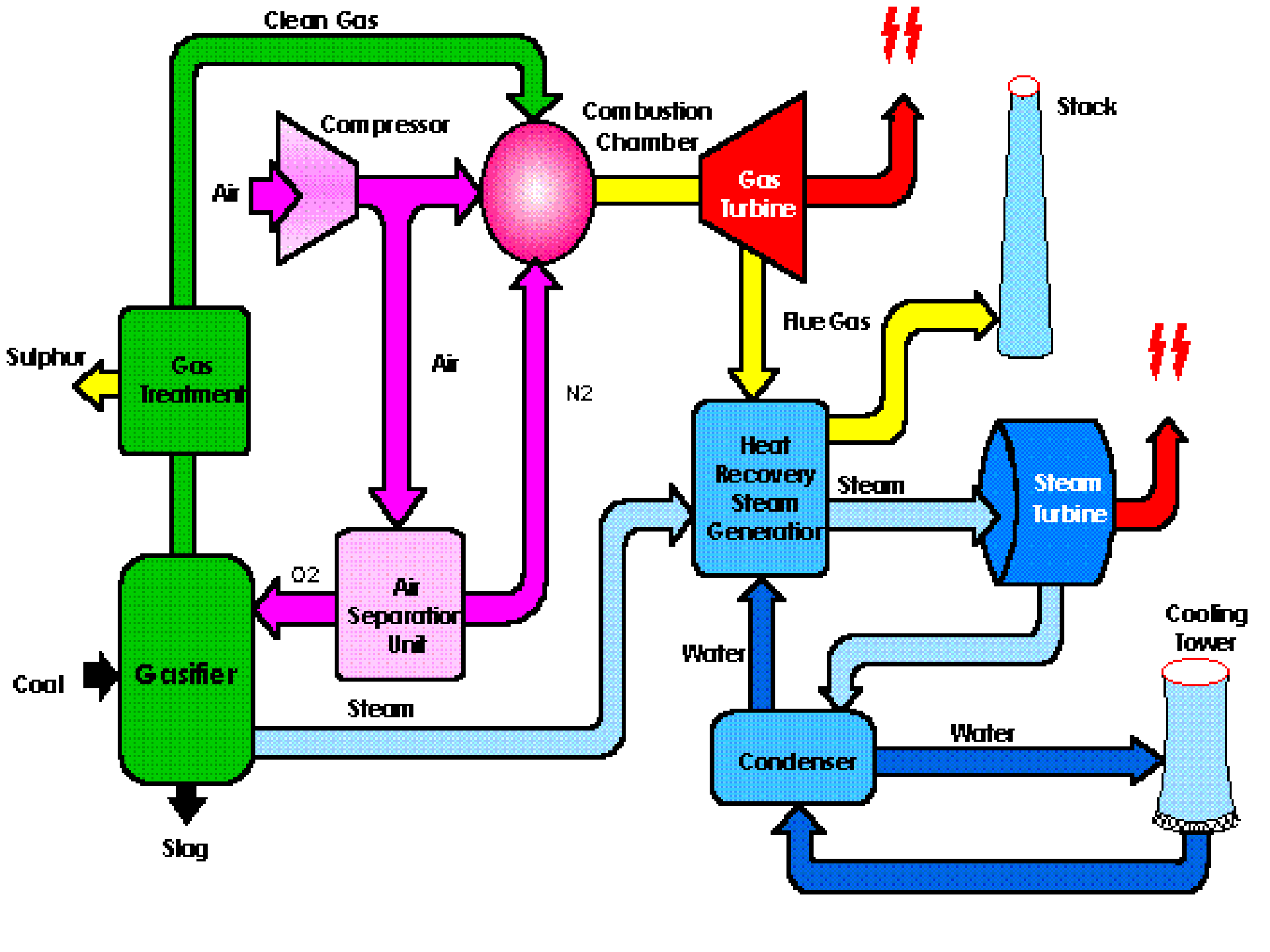
Slurry
Oxidant
Gasifier
Syngas cooler
Desulfurization
Particulate removal
Product Gas
Gas turbine
Air
Steam turbine
Coal
Banker
Wet mill
Slurry tank
Slag
Desulfurizer
Filter
Generator
Cooling Water Condenser
Transformer
Boiler Water
High Pressure Steam
Air
Nitrogen
H. R. S. G.
Stack
Air
Rectificator
Gasification
Combine Cycle Power Generation
Integrated High Pressure Air Separation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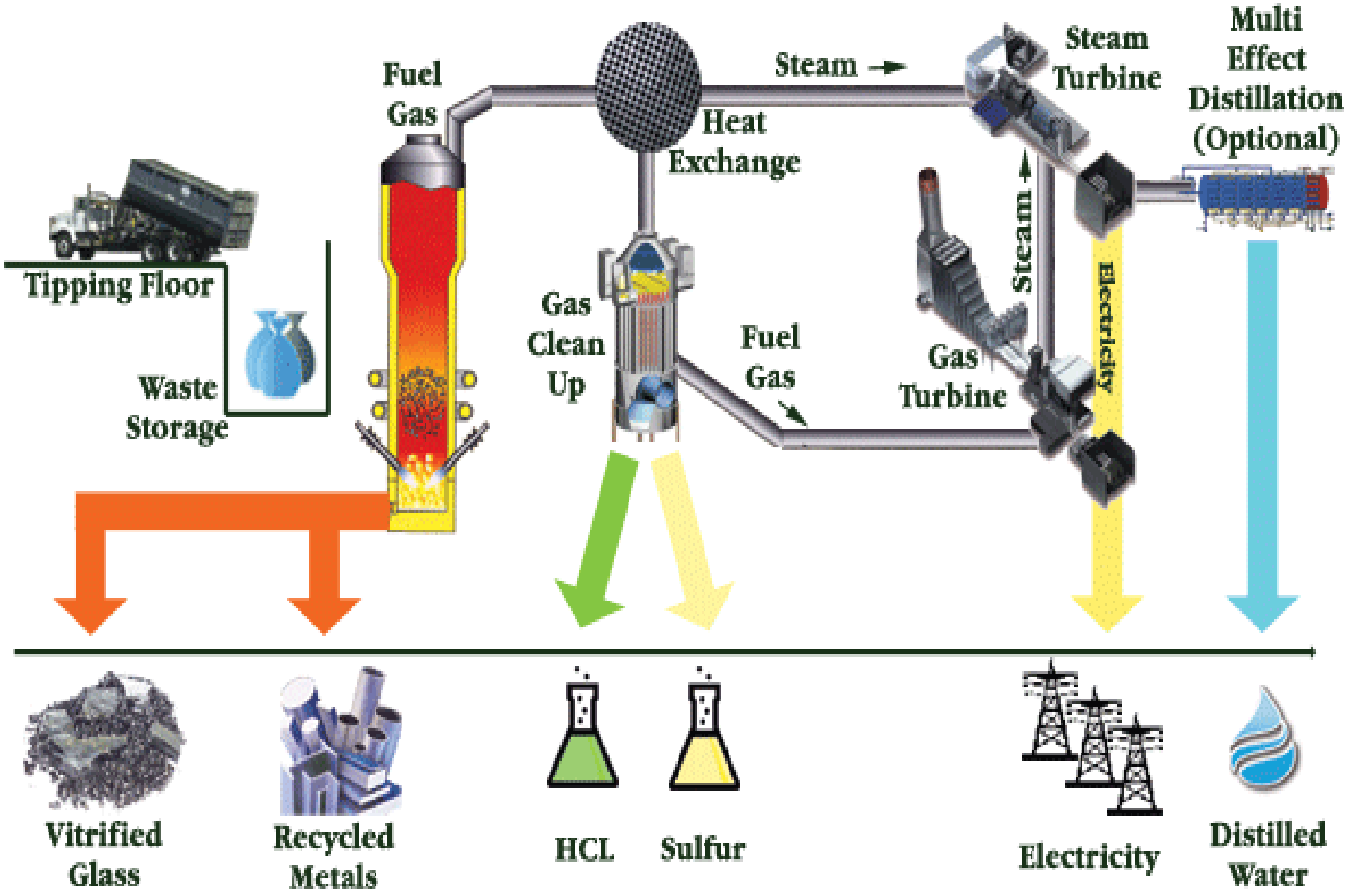
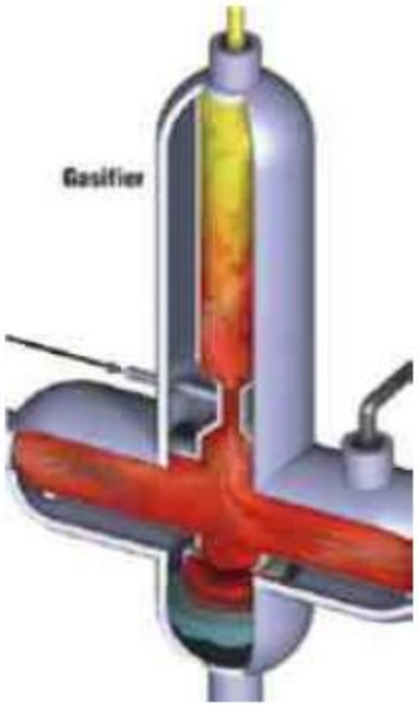
Compressor
Air
Combustion Chamber
Gas Turbine
Stack
Flue Gas
Sulphur
Gas Treatment
Air
N2
Heat Recovery Steam Generation
Steam
Steam Turbine
O2
Air Separation Unit
Cooling Tower
Water
Coal
Gasifier
Steam
Condenser
Water
Slag

IGCC for Municipal Solid Waste

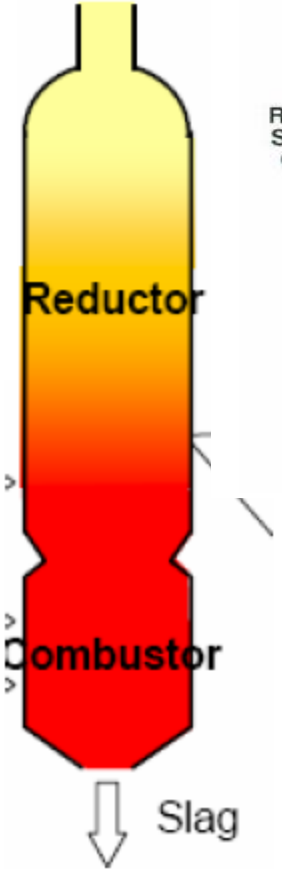


GASIFIER TYPES

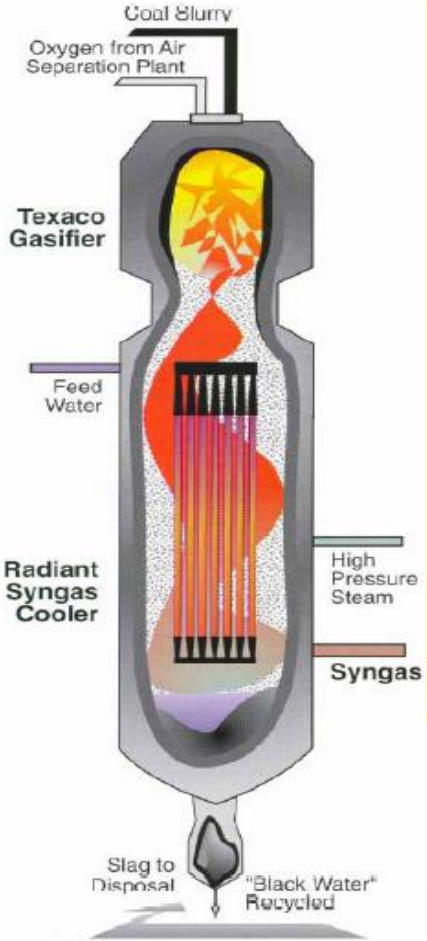
Manufacturer	Gasifier type	Application
ConocoPhillips	Coal- water slurry feed, Oxygen blown, refractory lined gasifier	wide range of coal
General Electric Energy (GE)	Coal-water slurry feed, O_2 blown, refractory lined gasifier	bituminous coal, pet-coke or blend of pet coke with low rank coal
Kellog Brown and Root (KBR)	dry feed, air blown transport reactor	low rank coal
Mitsubishi Heavy Industry (MHI)	dry feed, air blown	low rank coal
Shell	dry feed, coal is crushed, dried and fed into gasifier, oxygen blown, waterwall in gasifier	wide variety of feedstock



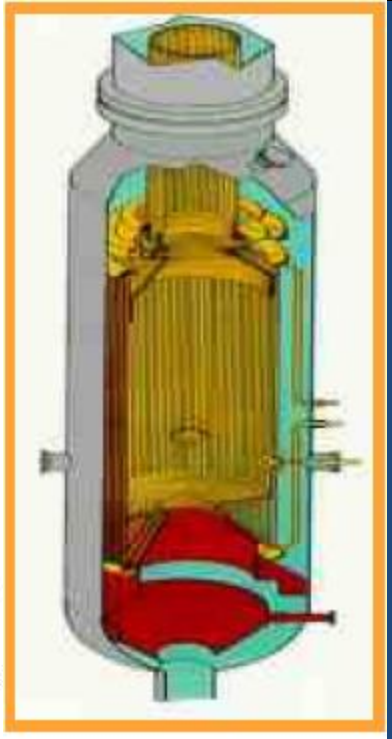
Source: ConocoPhillips



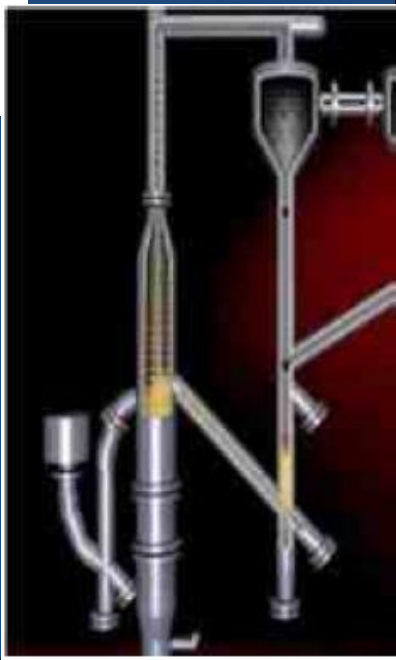
Source: MHII



Source: Shell



Kellog Brown and Root (KBR)



FUTURE DEVELOPMENT

- Improve gasifier performance
- Improve gas turbine efficiency
- Improve the heat exchanger system
- Reducing cost of air separation unit or switch to air blown process as Japan did
- Optimize energy saving in IGCC
- Improve control of the integrated system