POWER PLANT ENGINEERING

Course Code:A70353,JNTUH R-15

IV B-TECH, I-SEM

Prepared By
Mr. G. Sarat Raju, Assistant Professor.
Mrs. G. Karunya, Assistant Professor.
Mechanical Engineering.

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

UNIT – I

INTRODUCTION TO THE SOURCES OF ENERGY

Definition

A power station (also referred to as a generating station, power plant, powerhouse or generating plant) is an industrial facility for the generation of electric power.

Types of Power Plants

1.BASED ON INPUT ENERGY /FUEL

(a.)COAL thermal Power Plants

(b.) HYDRAULIC Power Plants

(c.) NUCLEAR Power Plants

(d.) GEOTHERMAL Power Plants

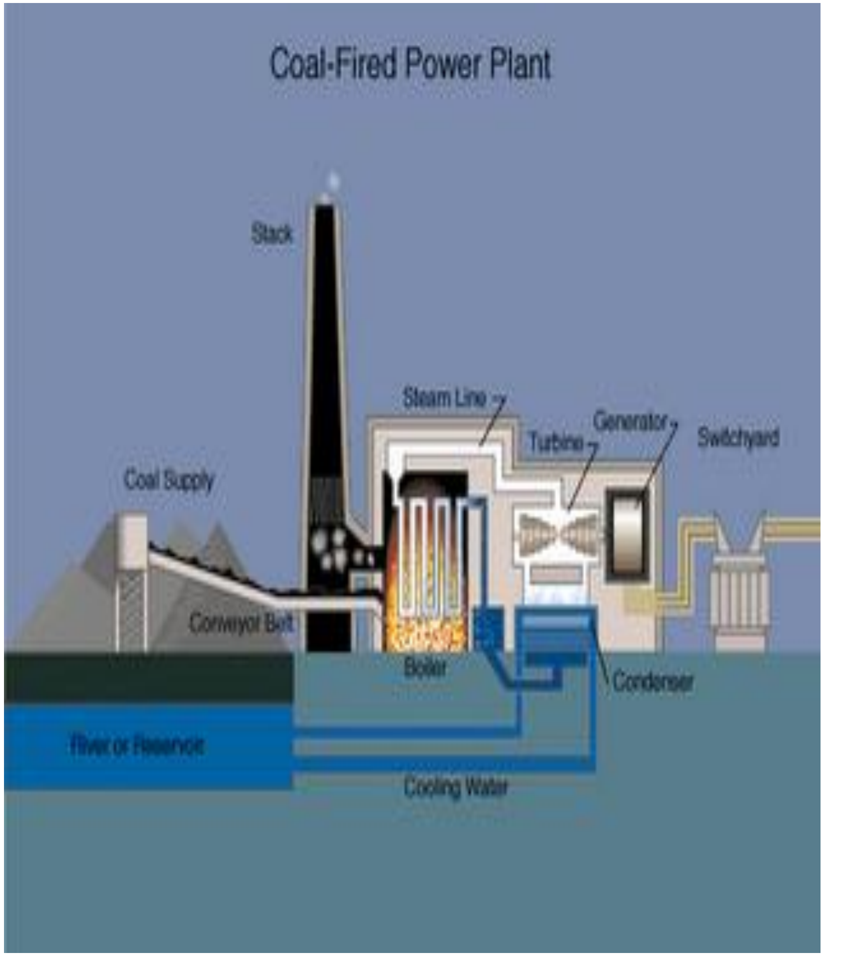
(e.) SOLAR Power Plants

(f.)WIND power plants

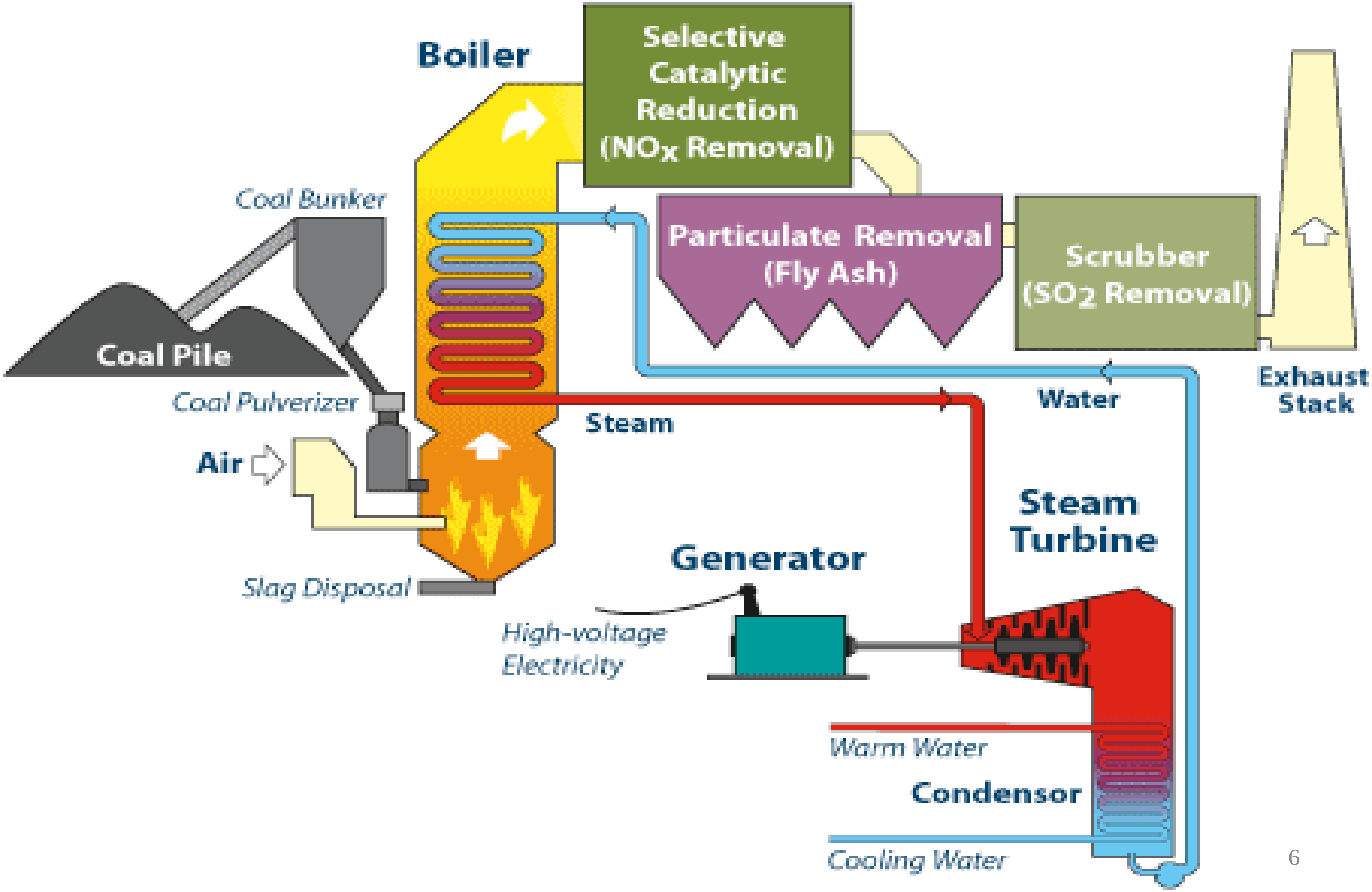
(g.)BIOMASS power plant

Coal Thermal Power Plant

- In coal thermal power plants The heat produce by burning fossil fuel materials boils water and transform it into steam.
- The steam is then piped to a turbine. -The impulses of turbine moves the turbine. -Finally, steam is condensed and move into the boiler to repeat the cycle.
- Rotation of the turbine rotates the generator to produce electricity.



POWER PLANT AND ITS COMPONENTS



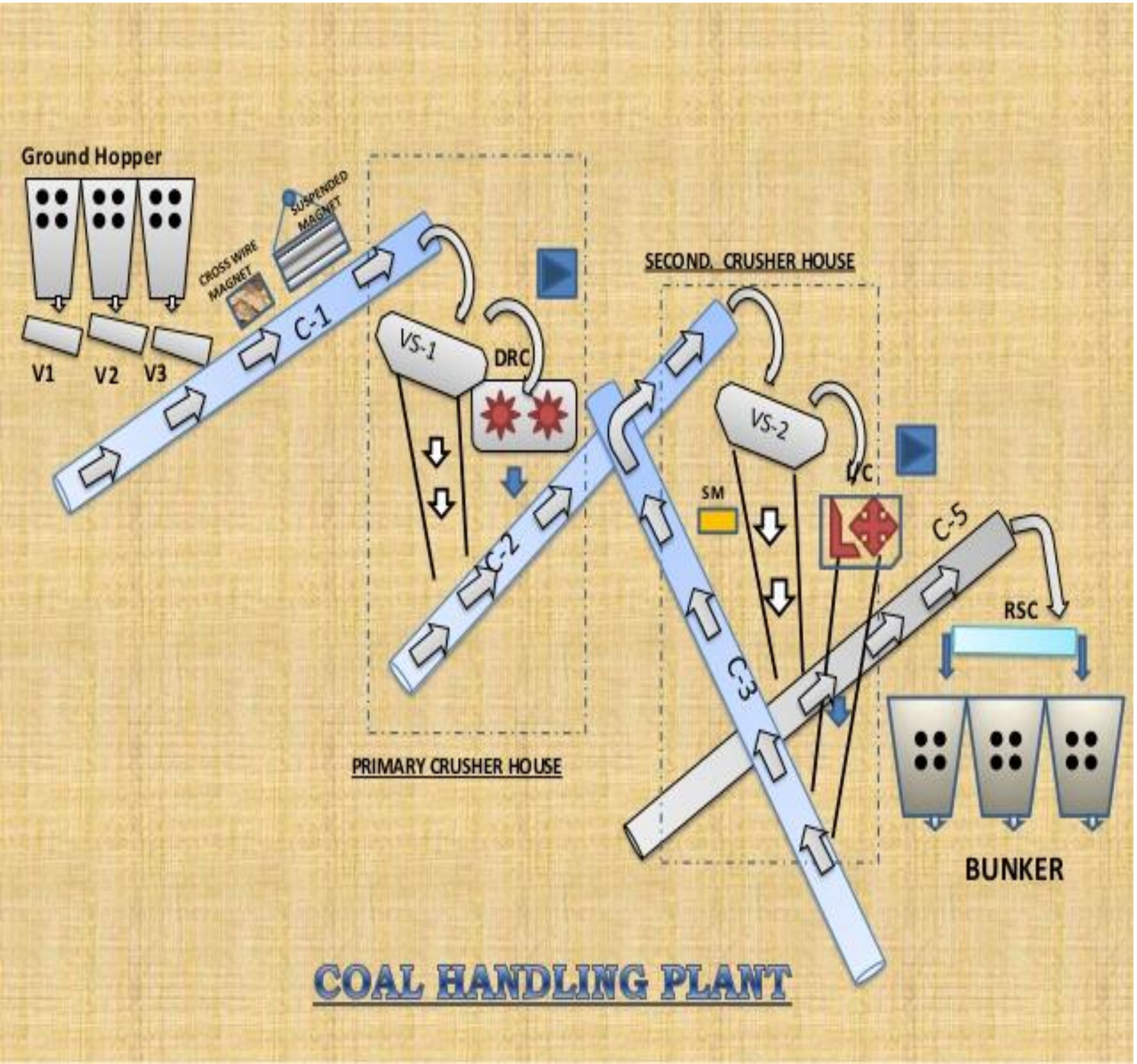
COMPONENTS

MAIN PARTS OF THE PLANT ARE :-

- **COAL HANDLING PLANT**
- **PRE TREATMENT and DM PLANT**
- **COOLING TOWER**
- **BOILER and its Components**
- **ASH HANDLING PLANT**
- **TURBINE GENERATOR**
- **TRANSFORMERS**
- **SWITCH YARD**

CHP (Coal Handling Plant)

PROCESS OF CHP



1. Here Sub-bituminous type ‘F’ grade coal is used in the boiler.

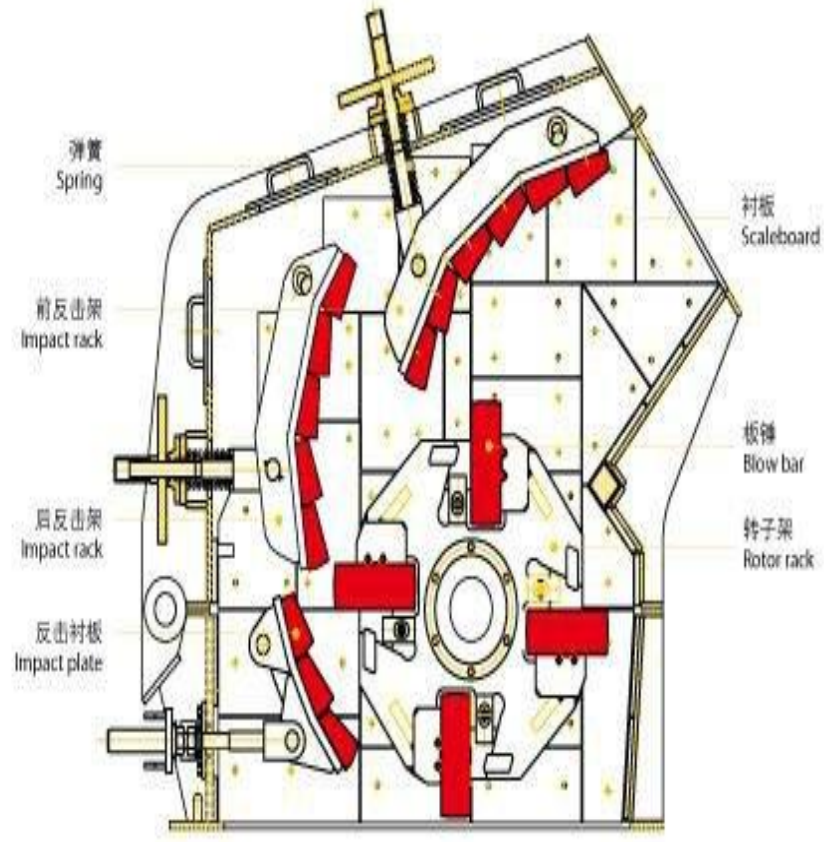
2. The size of the coal is 0.6 mm.

3. It is very low quality coal which contain 50-60% ash.

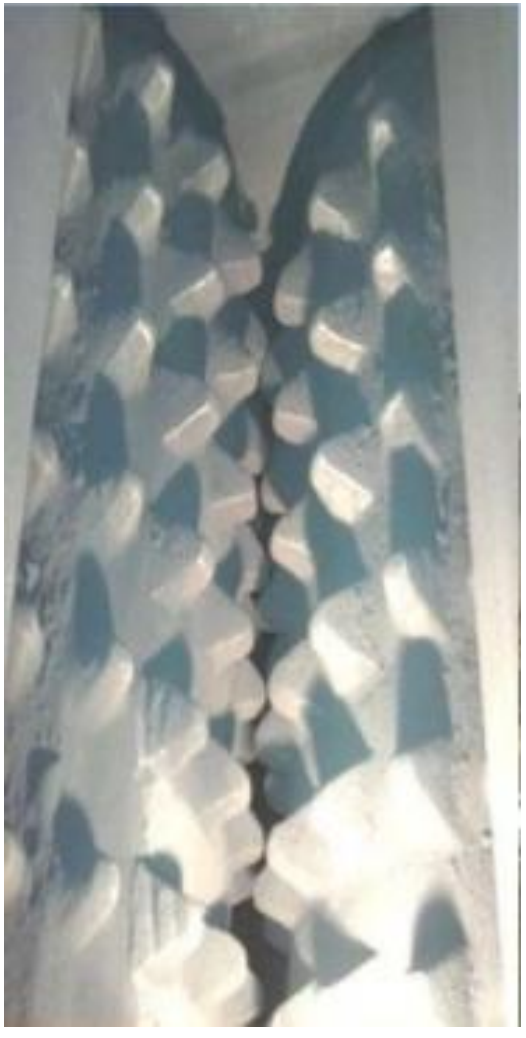
MAIN EQUIPMENT IN CHP

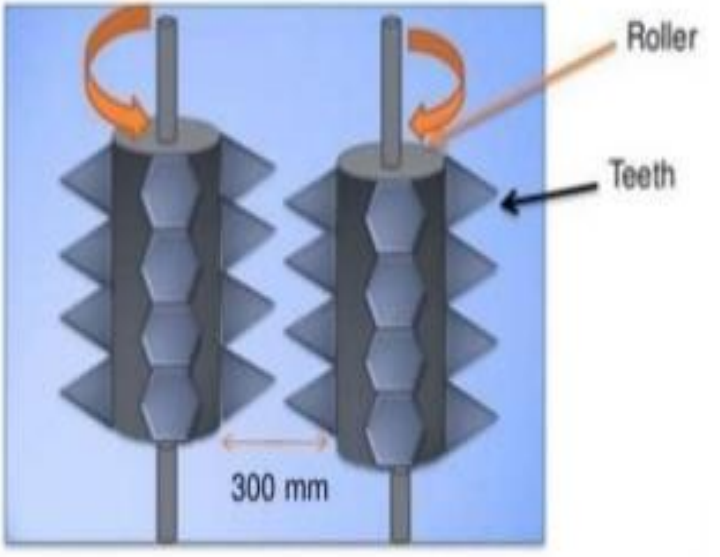
1. CRUSHER
2. VIBRATING SCREEN
3. CONVEYER
4. MAGNETIC SEPARATOR
5. VIBRO FEEDER

IMPACT CRUSHER

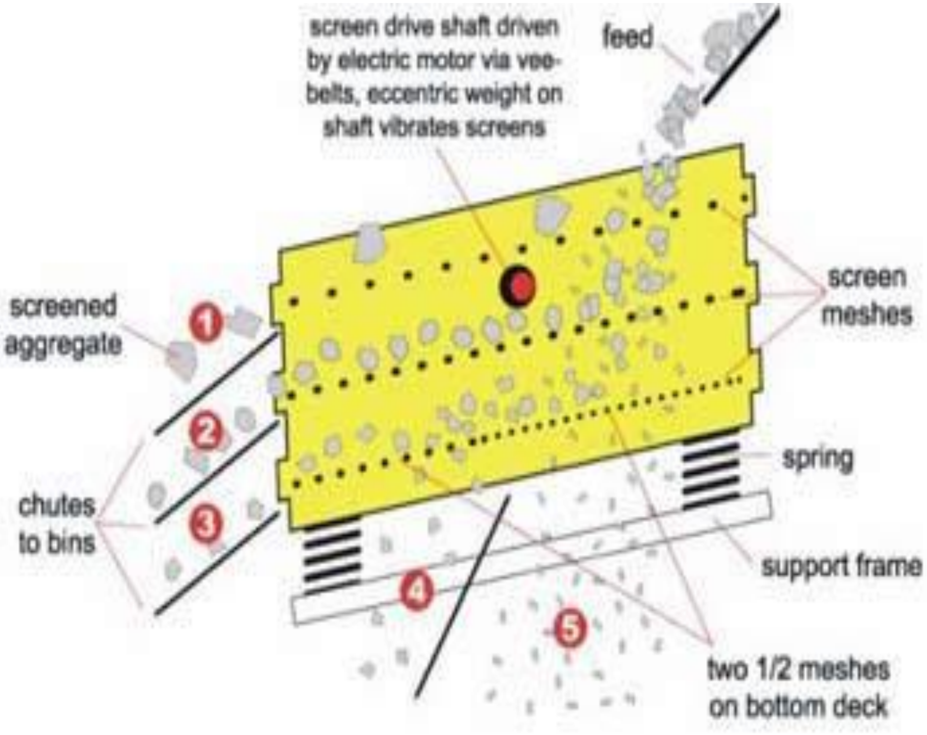


DOUBLE ROLL CRUSHER



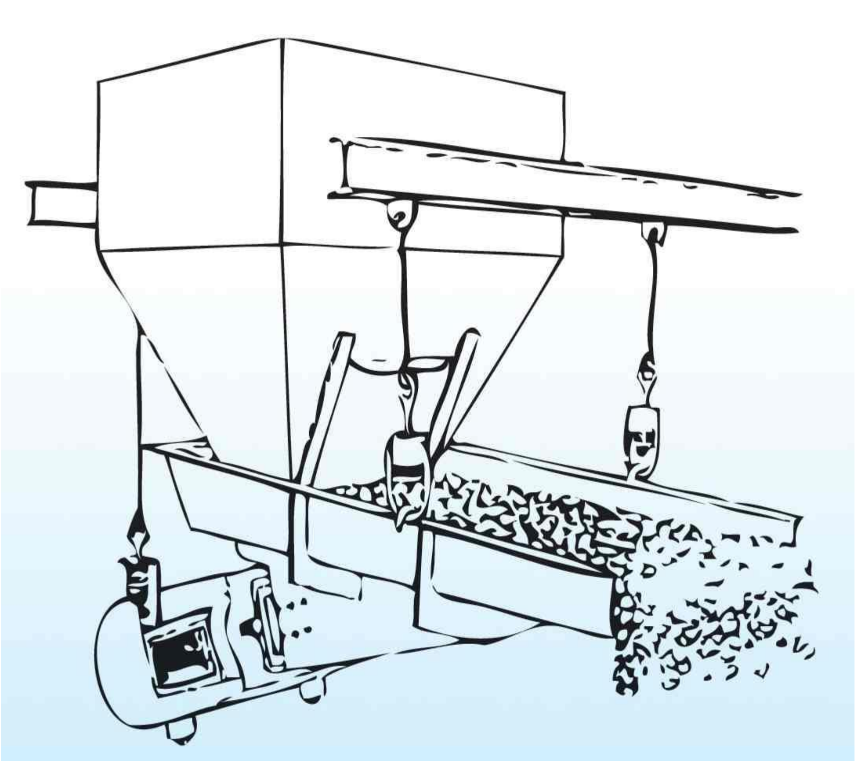


VIBRATING SCREEN



MAGNETIC SEPERATOR

VIBRO FEEDER



PROCESS OF PRE TREATMENT PLANT

RESERVOIR (Mahanadi, Kelo)

STEALING CHAMBER (Cl_2 dozing)

PARSELL FLUME (5% Polly Aluminium Chloride dozing)

INNER CELL CLEARIFIER (Removes sludges)

OUTER CELL CLEARIFIER

RGF (Rapid Gravity Filter)

FWS (Filtered Water Storage)

PROCESS OF DM PLANT

The main aim of DM Plant is to de-mineralised the raw water coming from a water source by chemical dosing which may be harmful to the pipeline and boilers.

ACF (Activated Carbon Filter) – contain charcoal to absorb chlorine.

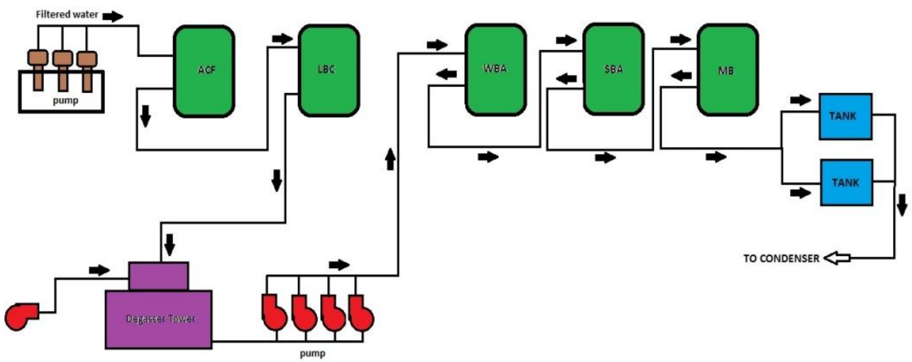
LBC (Layer Bed Cation) – contain resin to remove +ve minerals

DEGASSER TOWER – removes CO_2.

WBA (Weak Base Anion) – contain resin to remove –ve minerals.

SBA (Strong Base Anion) – it also contain resin to remove remaining charged minerals.

MB (Mixed Bed) - having both WBA and SBA to remove silica.



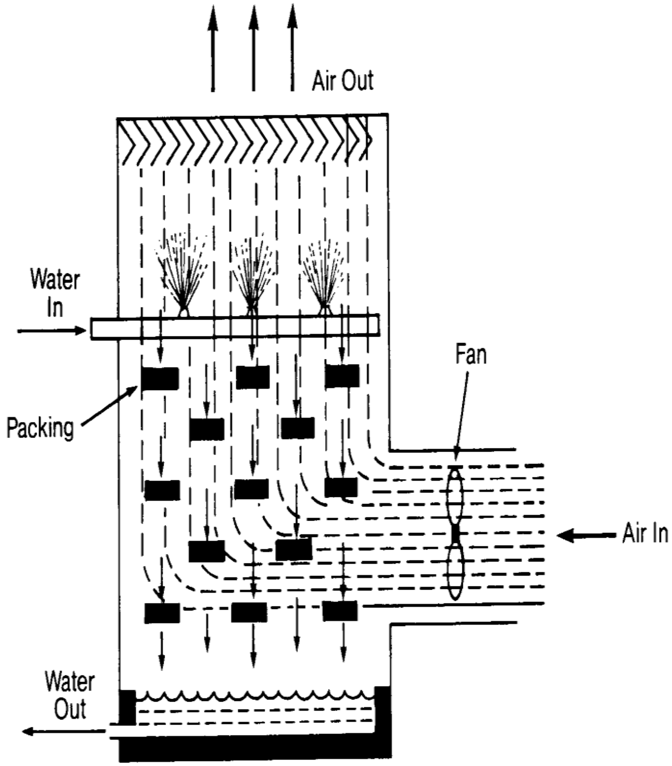
COOLING TOWER

1. The Warm Water is taken from the Condenser Tubes to the Cooling Tower.

2. This Breaks the water up into a Very Fine Spray Increasing the surface area of the Water Droplets making it easier to cool.

3. The cool water is collected in pond at the bottom of the cooling tower.

4. From here it pumped back tocondenser.



Reprinted with permission from POWER

BOILER AND ITS COMPONENTS

1. To produce steam boiler converts energy, in the form of coal, into steam.

2. The boiler is lined with steel tubing in which pure water is turned to steam by the heat created from the burning of coal.

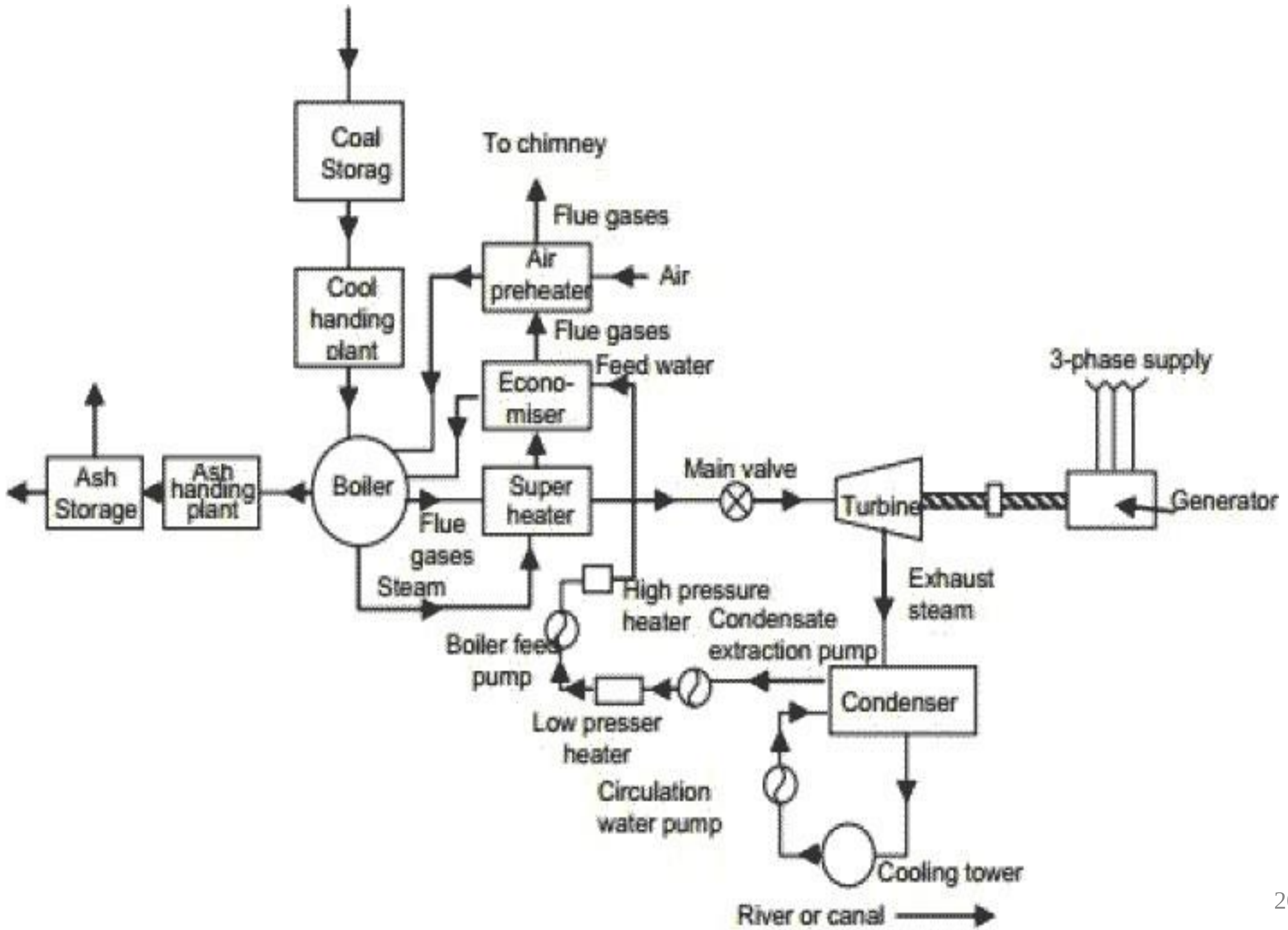
3. The plant mainly of two types:-
   I. AFBC (Air Fluidise Bed Combustion)
   II. WHRC (Waste Heat Recovery Boiler)

4. BOILER CAPACITY– 165 TPH (Ton Per Hour)

5. STEAM PRESSURE– 90 Kg/Cm^2

6. STEAM TEMPERATURE– 540 ^{O}c

layout of steam power plant



BOILER COMPONENTS

Forced Draft (Fd) Fan

This fan forces the atmospheric air through the boiler furnace and pushes out the hot gases from the furnace through super heater, economizer, and air heater to stacks.

Induced Draft (Id) Fan

1. This fan is provided at the outlet of the boiler, that is just before the stack.
2. This fan sucks hot gases from the furnace through the super heaters, economizer and discharges gas into the stack.

Primary Air (Pa) Fan

This fan are high pressure fans used to supply the air for the Transportation of coal directly to furnace.

FD
FAN

ID
FAN

PA
FAN

ECONOMIZER

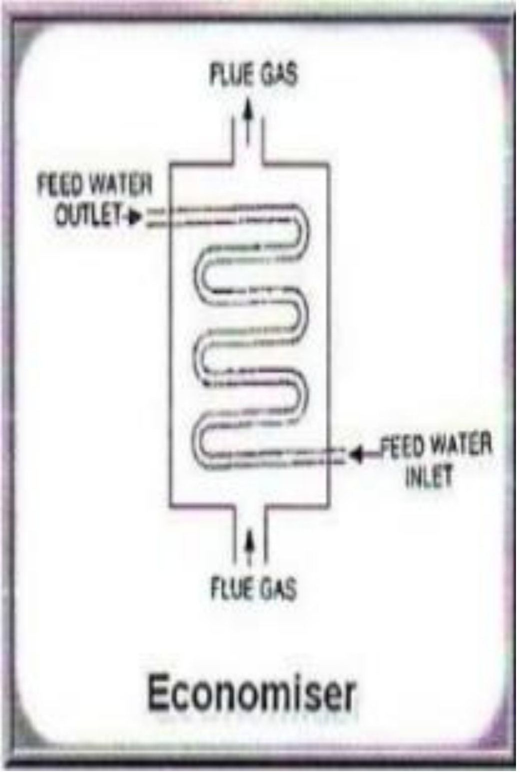
1. Flue gas coming out of the boiler carries lots of heat.
2. The economizer extracts a part of heat from the flue gases and uses for heating the feed water. thus improves the efficiency of plant.

SUPERHEATER

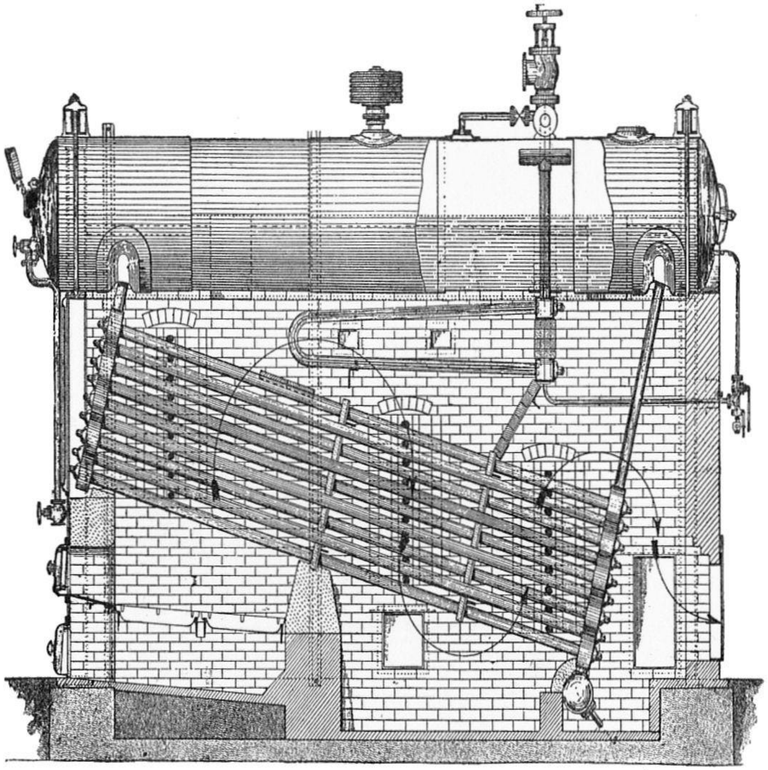
1. Super heater is used to remove moisture content from the steam.
2. Super heater raises the temperature of steam above 540 ^{o}C.
3. Advantages of super heater :-
   i. increase efficiency.
   ii. reduces corrosion of turbine blades.

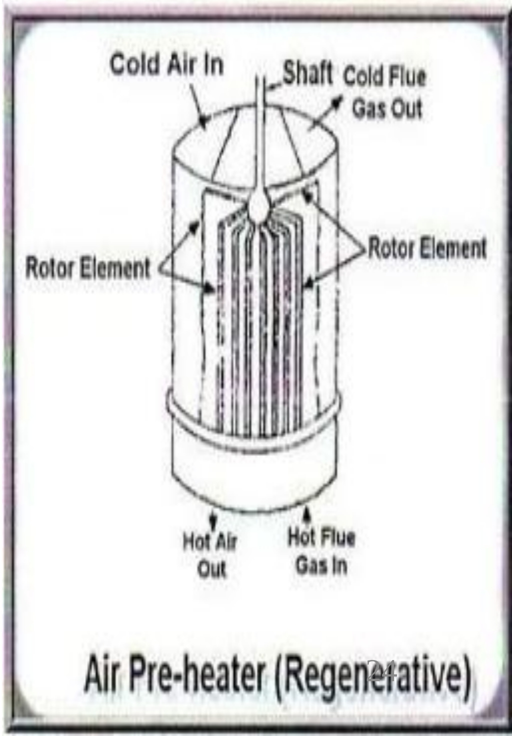
AIR PREHEATER (APH)

1. It is used to preheat the air before entering into furnace.
2. It is a heat exchanger in which some further heat is extracted from the flue gases and use to heat the coming air from combustion.



Economiser

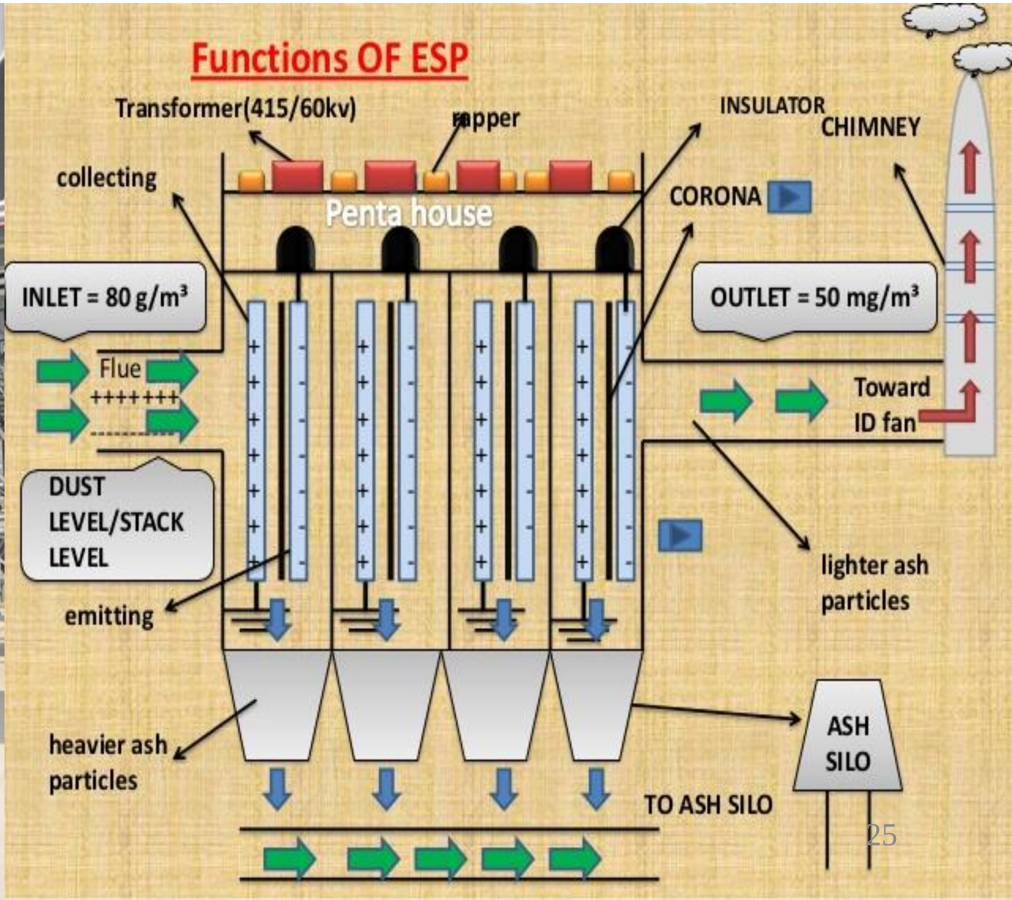




Air Pre-heater (Regenerative)

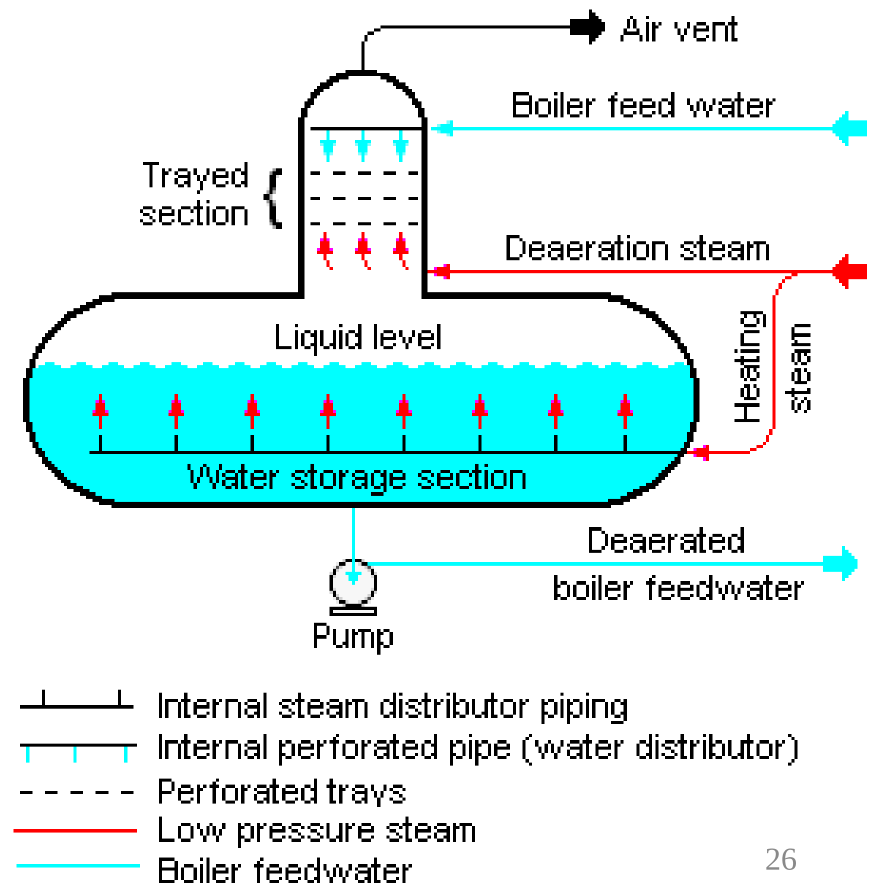
ELECTROSTATIC PRECIPITATOR

1. It is designed to trap and remove dust particles from and exhaust gas stream of an industrial process.
2. The precipitation process involves 3 main functions:-
   i. particle charging
   ii. particle collection
   iii. removal of particles



DEAERATOR

A deaerator is a device that is widely used for the removal of oxygen and other dissolved gases from the feed water. in particularly, dissolved oxygen in boiler feed waters will cause serious corrosion damage in steam systems by attaching to the walls of metal piping and other metallic equipment and forming oxides (rust).



CONDENSER

1. Here the steam is condensed back into water and pumped back to the boiler.
2. This happens via a series of low and high pressure heaters.

CONDENSATE EXTRACTION PUMP

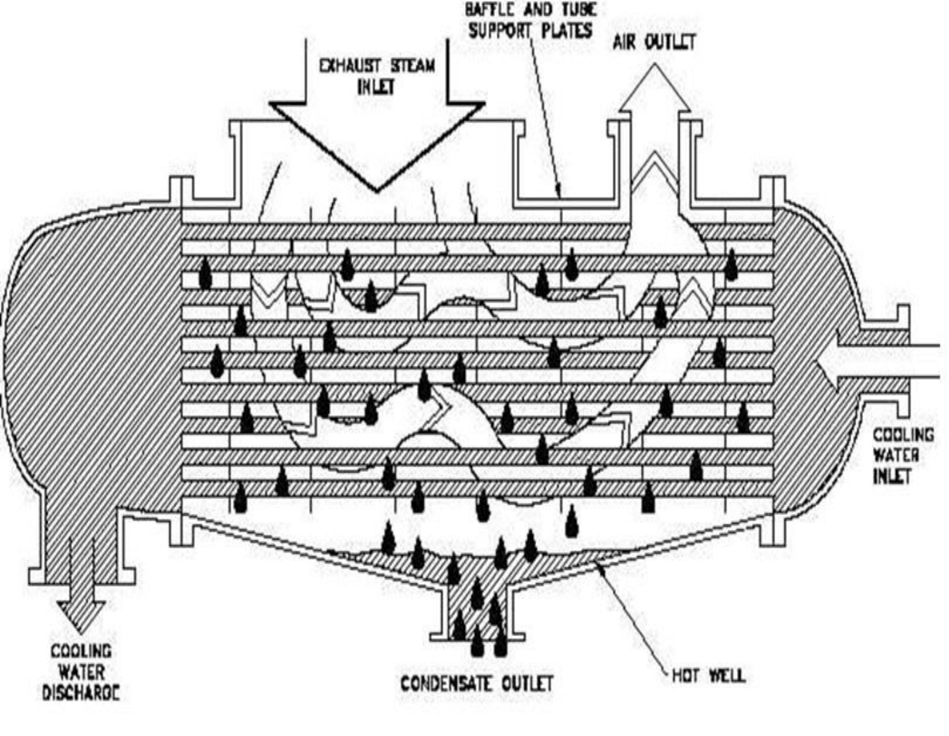
The condensate water is drawn from the condenser by extraction pump and send it to low pressure feed heater.

LOW PRESSURE FEED HEATER (LP HEATER)

1. Feed water from the condensate extraction pumps pass through low pressure heater.
2. Steam is used to heat the feed water.

HIGH PRESSURE HEATER

With similar purpose, the high pressure feed heaters are the last stage of feed water heating before the feed water enters the boiler system at the economizer.


BAFFLE AND TUBE SUPPORT PLATES
EXHAUST STEAM INLET
AIR OUTLET
COOLING WATER INLET
COOLING WATER DISCHARGE
CONDENSATE OUTLET
HOT WELL


CE
P


LP1
LP2
LP


HP

BOILER FEED PUMP

1. The boiler feed pump pumps the water into the boiler, overcoming pressure of 150 kg/cm^2.
2. The pump is driven by an electric motor.
3. The pump run in 4130 rpm and the motor runs in 1490 rpm.

CIRCULATING WATER PUMPS

The circulating water pumps are used to circulate the water from cooling tower to the condenser and back again.

COMPRESSOR HOUSE

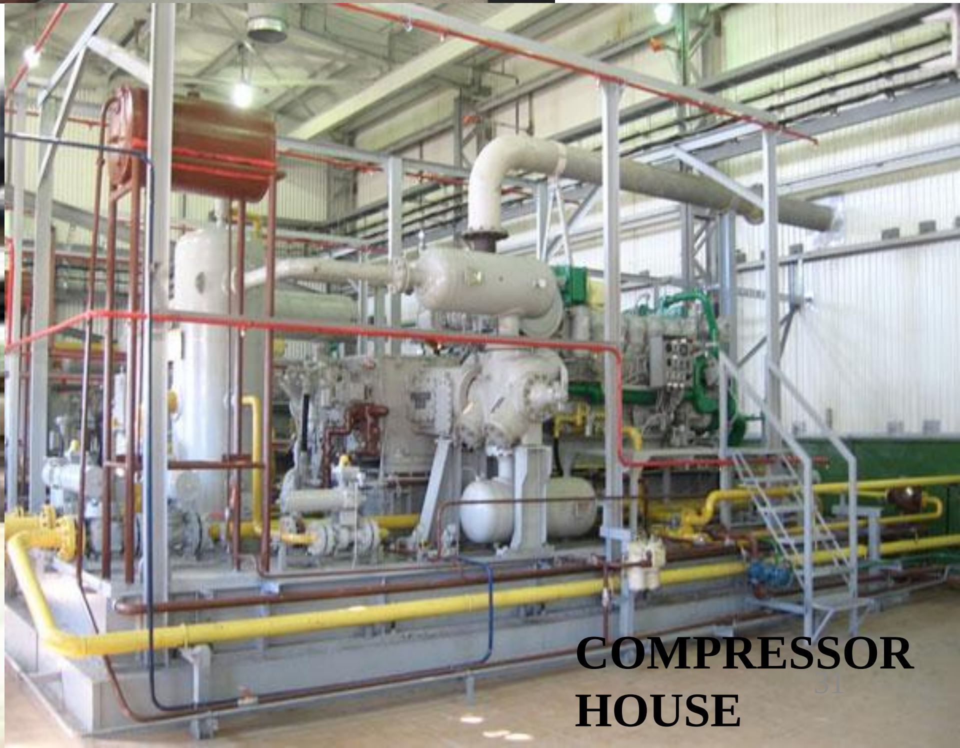
1. The main purpose of the compressor house is to provide or supply the high pressure air to the different components in plant.
2. There are 2 types of compressed air:-

i. **SERVICE AIR** which contains moisture and is supply to ash handling plant and other services where moisture not damage any equipment.

ii. **INSTRUMENT AIR** which contain no moisture in air and this air is used in Pneumatic valves.


BFP


CIRCULATING
PUMP


COMPRESSOR
HOUSE

ASH HANDLING PLANT

After the coal is burn the ash of the coal remains in the esp system so to remove that ash from the plant there is an ash handling plant just near the boiler. the wet ash is dumped in dumping area and the dry ash is used in brick and cement making.

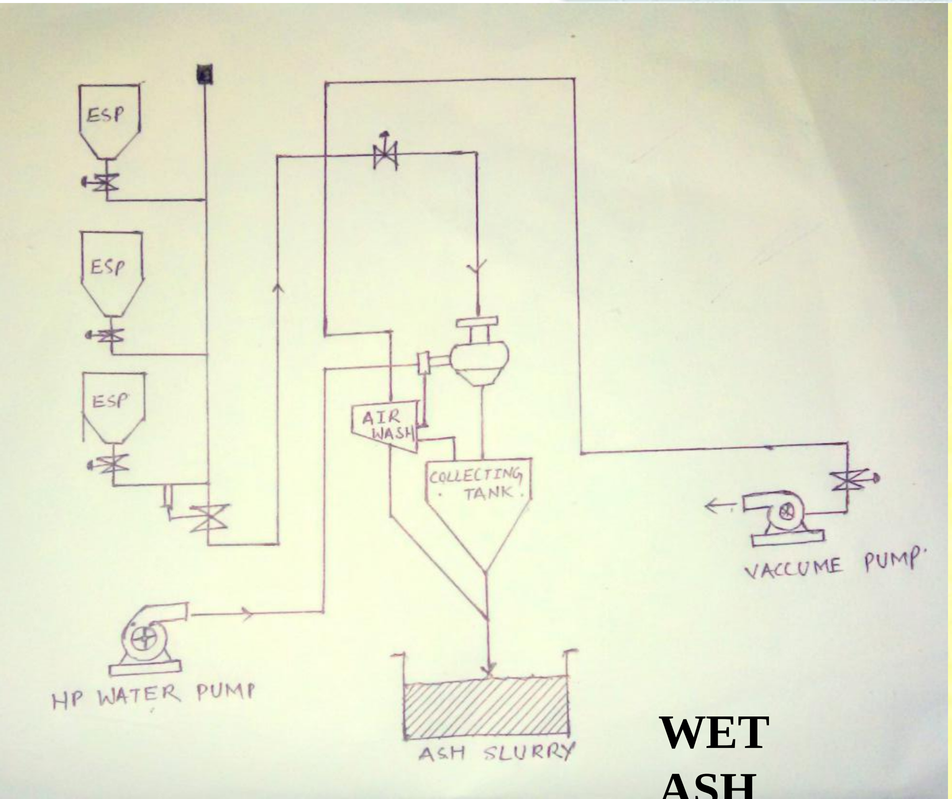
DRY ASH SYSTEM

Fly ash is considered to be collected in esp. hoppers. fly ash from esp. hoppers extracted by vacuum pumps up to intermediate surge hopper cum bag filter for further dry conveying to fly ash silo.

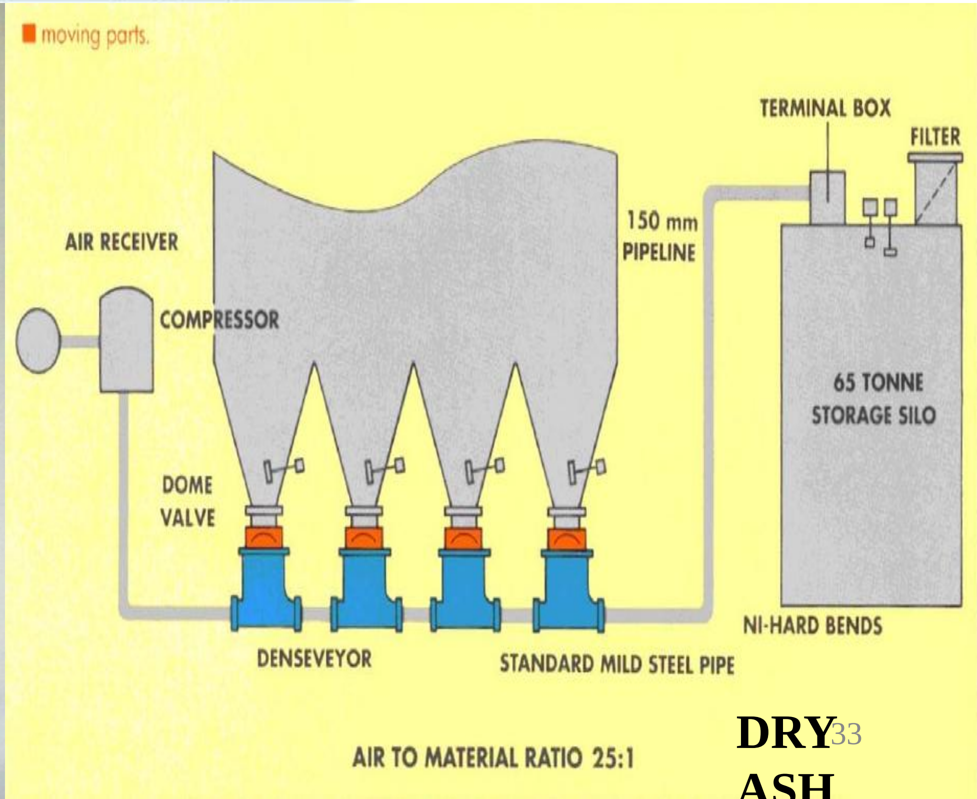
WET ASH SYSTEM

Bottom ash slurry and fly ash slurry shall be pumped from the common ash slurry sump up to the dyke area which is located at a distance from slurry pump house.

SILO



WET ASH



DRY ASH

TRANSFORMER

1. Transformer is the most convenient device for transformer of power from one voltage to another voltage at the same frequency.
2. It works in the principle of electromagnetic induction.
3. Transformers are of two types :-
   i. step-up transformer
   ii. step-down transformer

SWITCH YARD

Electrical switchyards are usually part of substation where electricity is transformed from one voltage to another for the transmission , distribution.

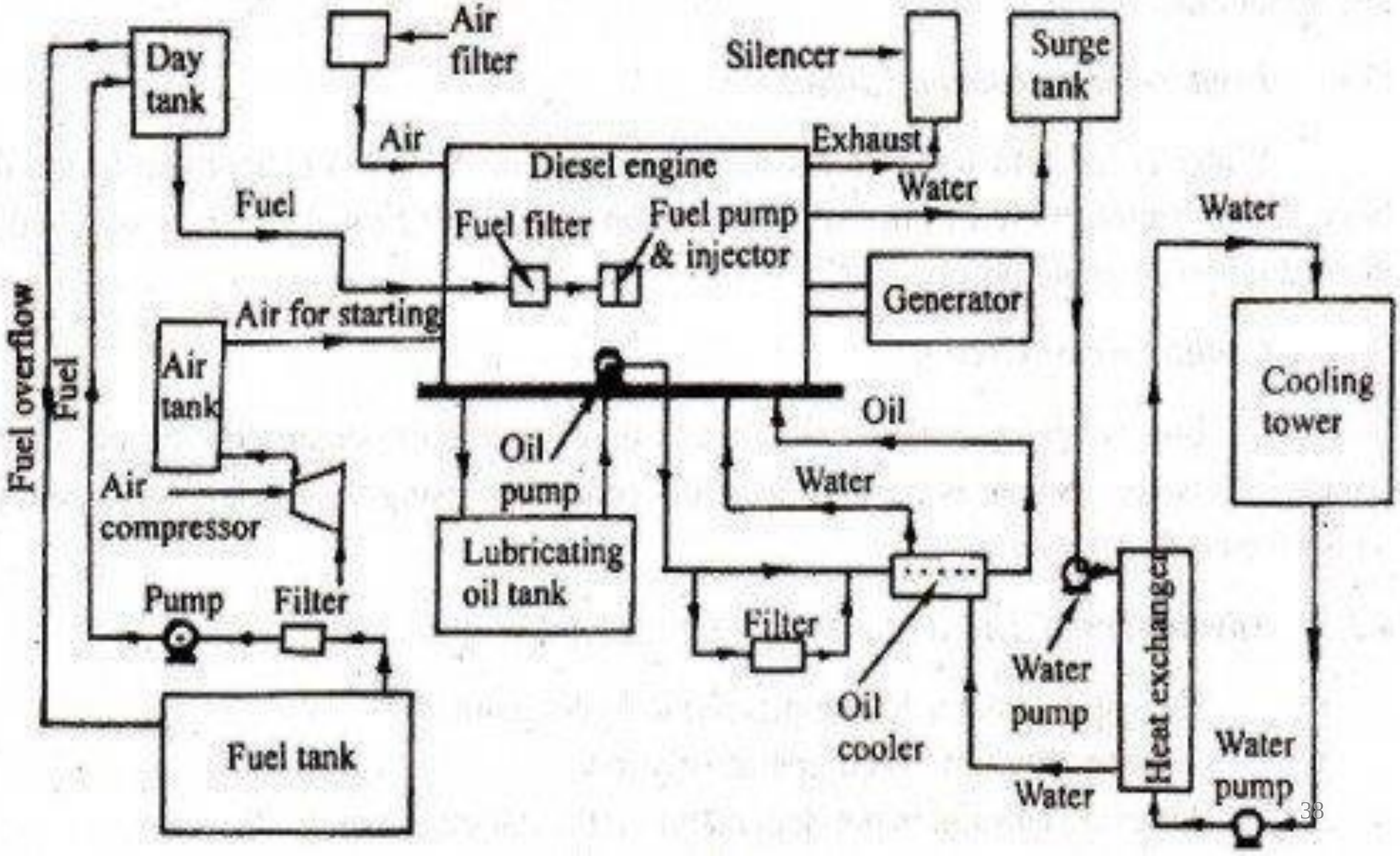
UNIT-II

INTERNAL COMBUSTION ENGINE PLANT

INTERNAL COMBUSTION ENGINE PLANT:

- DIESEL POWER PLANT
- The oil engines and gas engines are called Internal Combustion Engines. In IC engines fuels burn inside the engine and the products of combustion form the working fluid that generates mechanical power. Whereas, in Gas Turbines the combustion occurs in another chamber and hot working fluid containing thermal energy is admitted in turbine.

LAYOUT OF DIESEL POWER PLANTS WITH AUXILLIARIES:



FUEL SUPPLY SYSTEM:

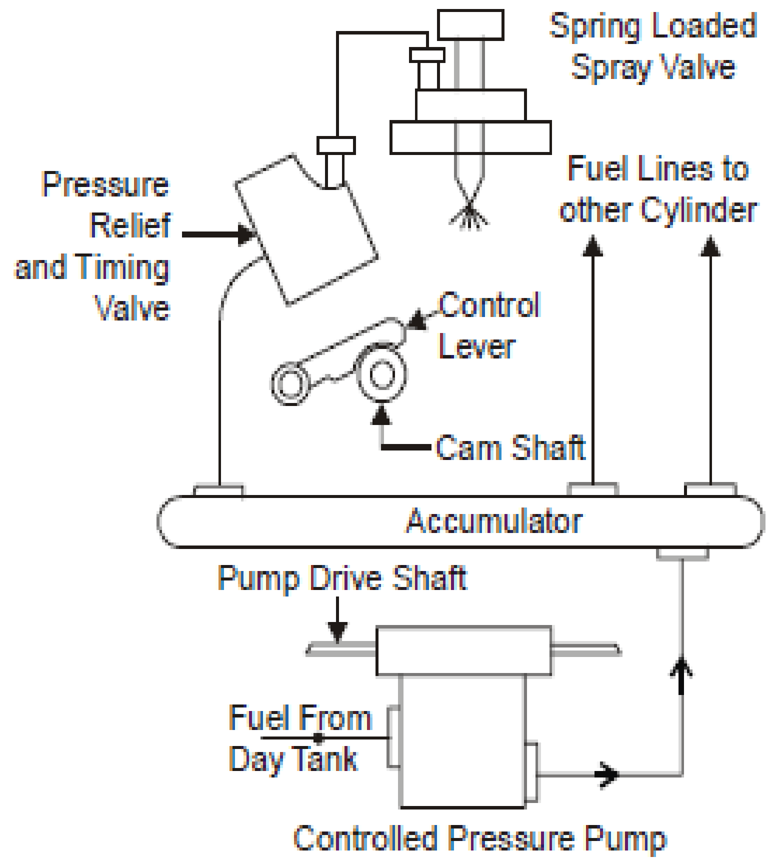
The five **essential functions** of a fuel injection system are:

- To deliver oil from the storage to the fuel injector.
- To raise the fuel pressure to the level required for atomization.
- To measure and control the amount of fuel admitted in each cycle.
- To control time of injection.
- To spray fuel into the cylinder in atomized form for thorough mixing and burning.

- The above functions can be achieved in a variety of ways. The following are the systems, which are usual on power station diesels:
  - Common Rail.
  - Individual Pump Injection.
  - Distributor.

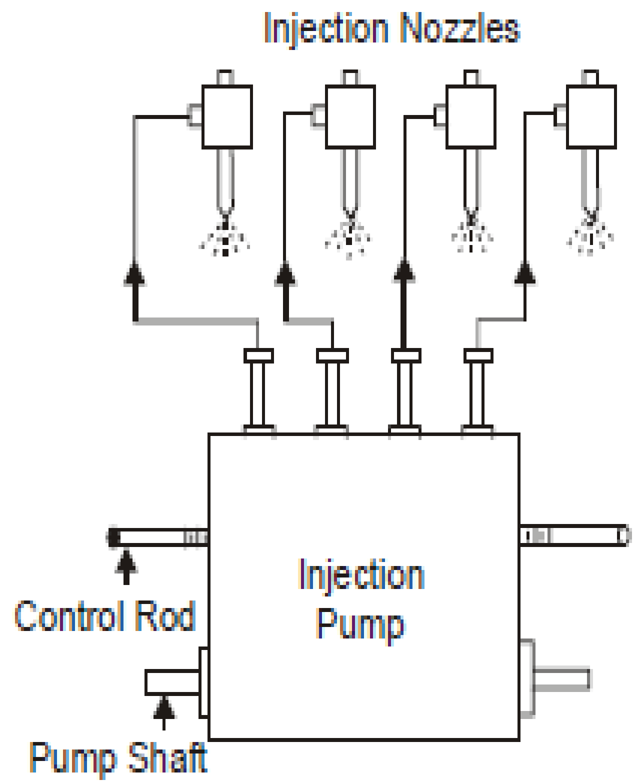
COMMON RAIL INJECTION

It incorporates a pump with built in pressure regulation, which adjusts pumping rate to maintain the desired injection pressure.



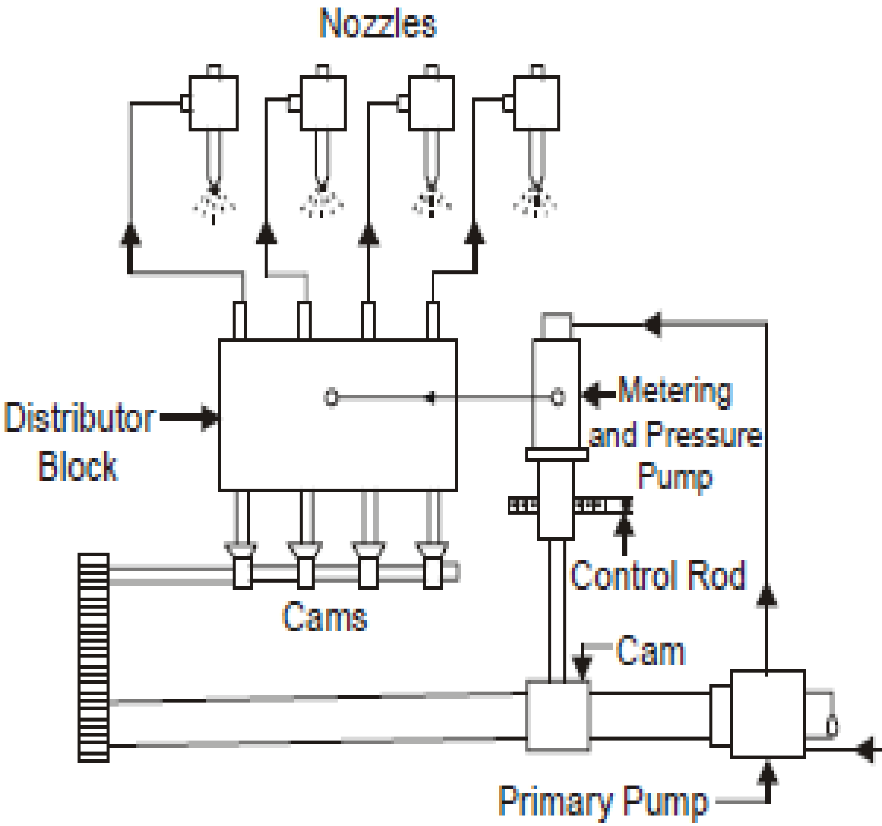
INDIVIDUAL PUMP INJECTION

In this system, each fuel nozzle is connected to a separate injection pump, The pump itself does the measuring of the fuel charge and control of the injection timing. The delivery valve in the nozzle is actuated by fuel-oil pressure.



DISTRIBUTOR SYSTEM

In this system, the fuel is metered at a central point *i.e.*, the pump that pressurizes, meters the fuel and times the injection. From here, the fuel is distributed to cylinders in correct firing order by cam operated poppet valves, which open to admit fuel to nozzles.

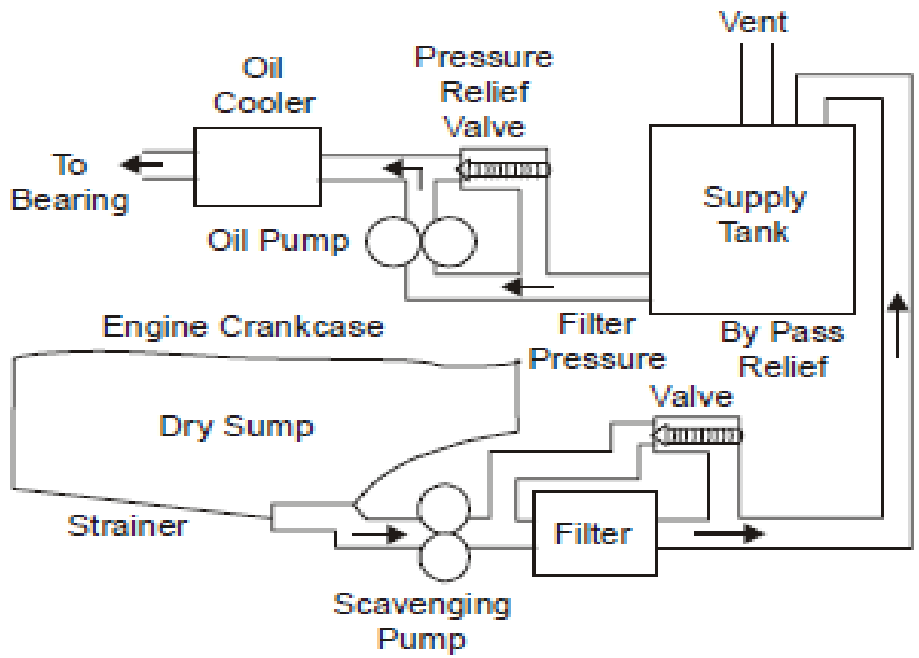


LUBRICATION SYSTEM

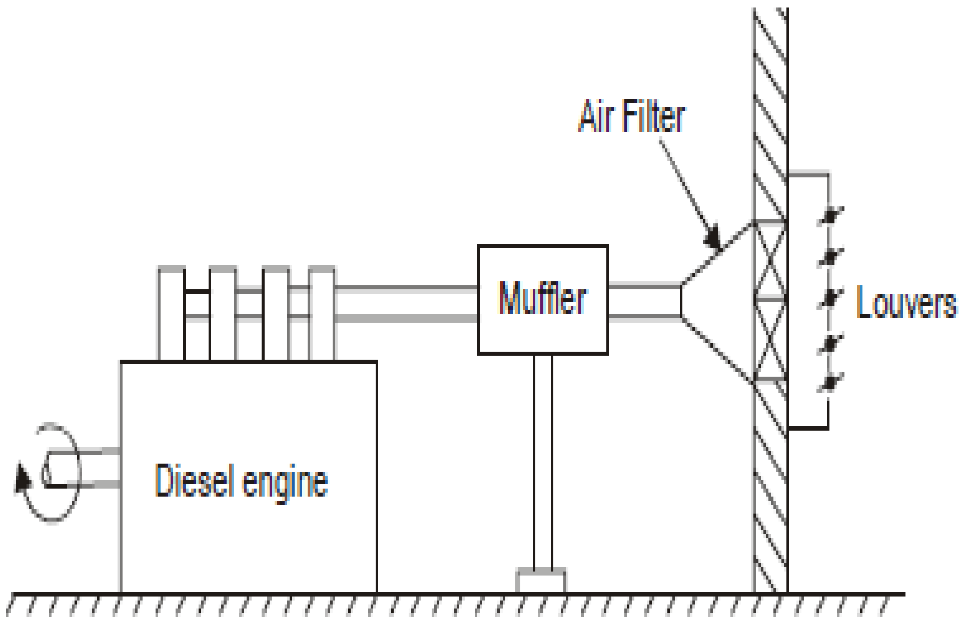
The main function of lubricant is to,

- To reduce friction and wear between the parts having relative motion by minimizing the force of friction and ensures smooth running of parts.
- To seal a space adjoining the surfaces such as piston rings and cylinder liner.
- To clean the surface by carrying away the carbon and metal particles caused by wear.
- To absorb shock between bearings and other parts and consequently reduce noise.

LUBRICATION SYSTEM

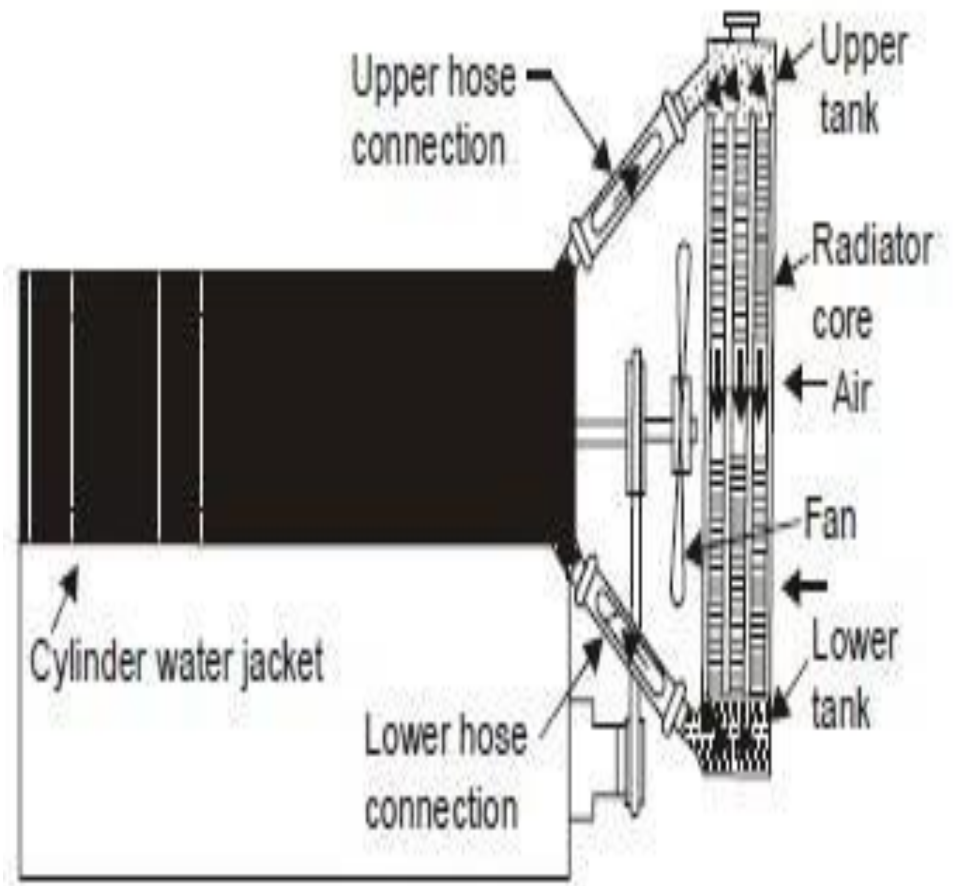


AIR INTAKES AND ADMISSION SYSTEM



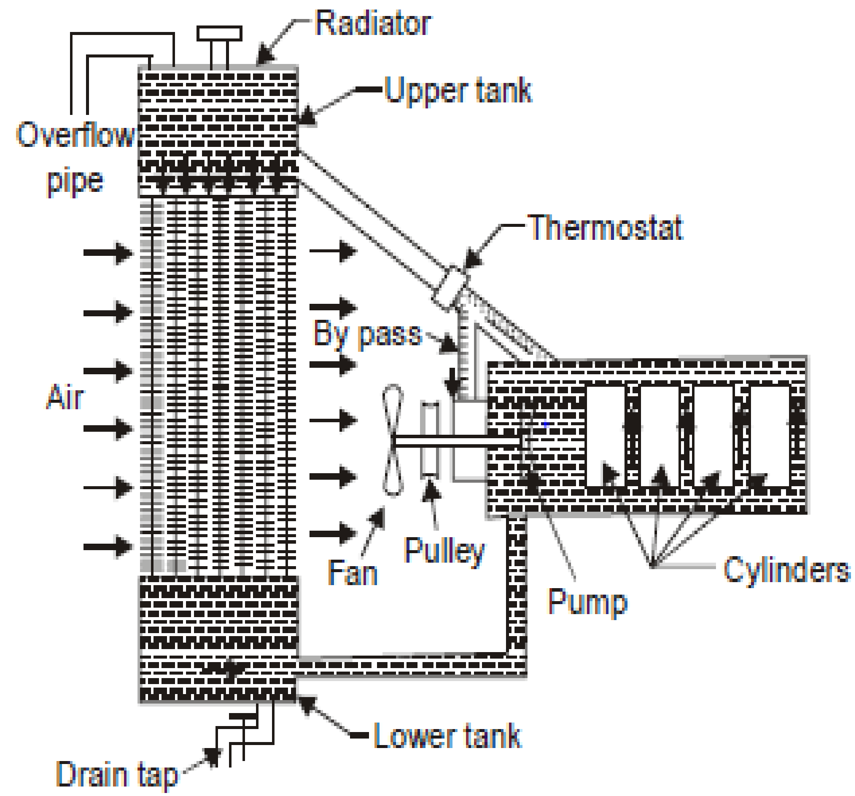
COOLING SYSTEM

NATURAL CIRCULATION SYSTEM: The system is closed one and designed so that the water may circulate naturally because of the difference in density of water at different temperatures.



FORCED CIRCULATION COOLING SYSTEM

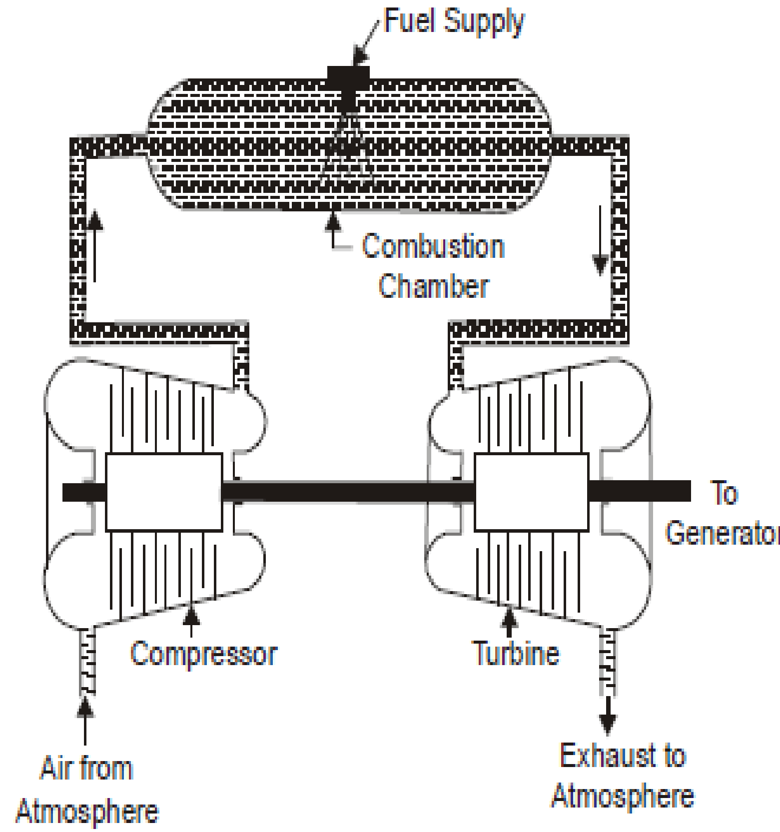
The system consists of pump, water jacket in the cylinder, radiator, fan and a thermostat.



GAS TURBINE PLANT:

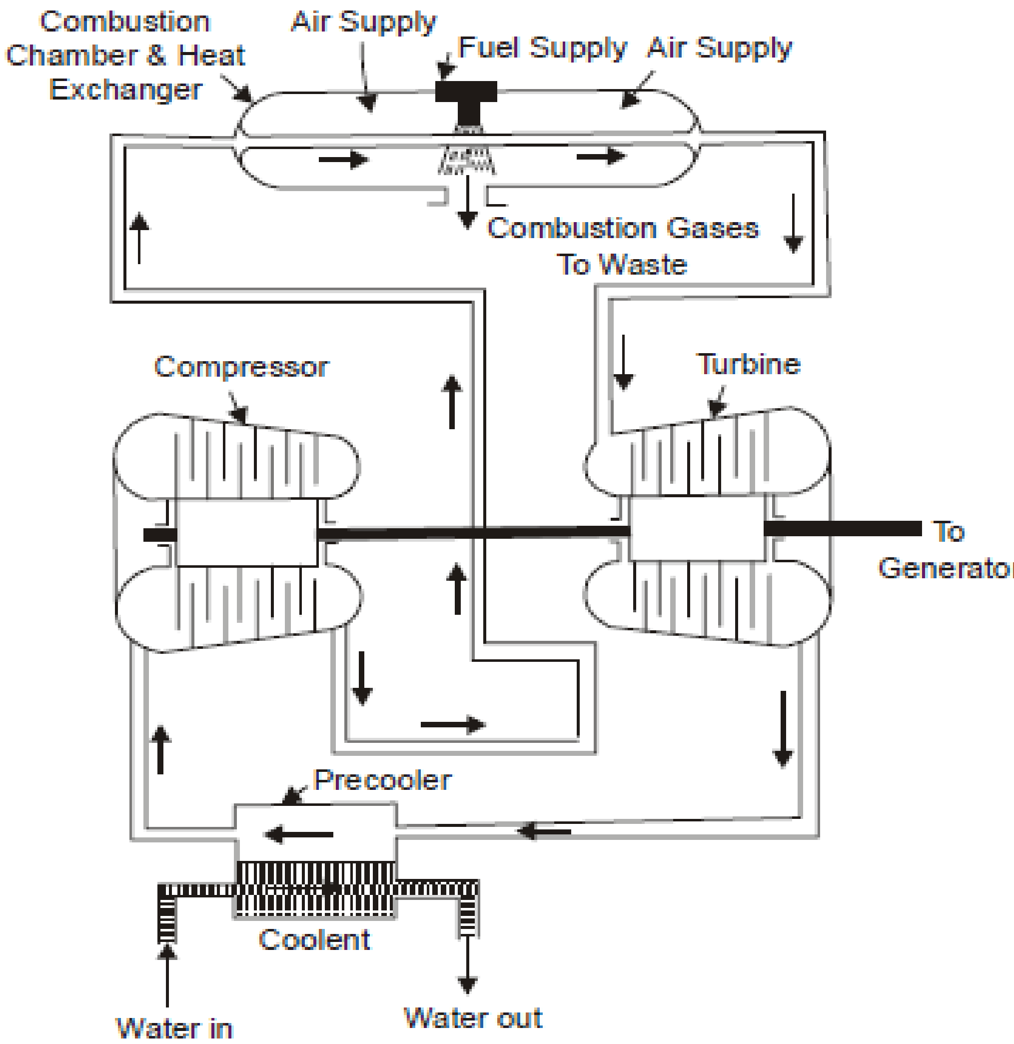
- **OPEN CYCLE GAS TURBINE POWER PLANT**

A simple open cycle gas turbine consists of a compressor, combustion chamber and a turbine as shown in Fig. The compressor takes in ambient air and raises its pressure. Heat is added to the air in combustion chamber by burning the fuel and raises its temperature.



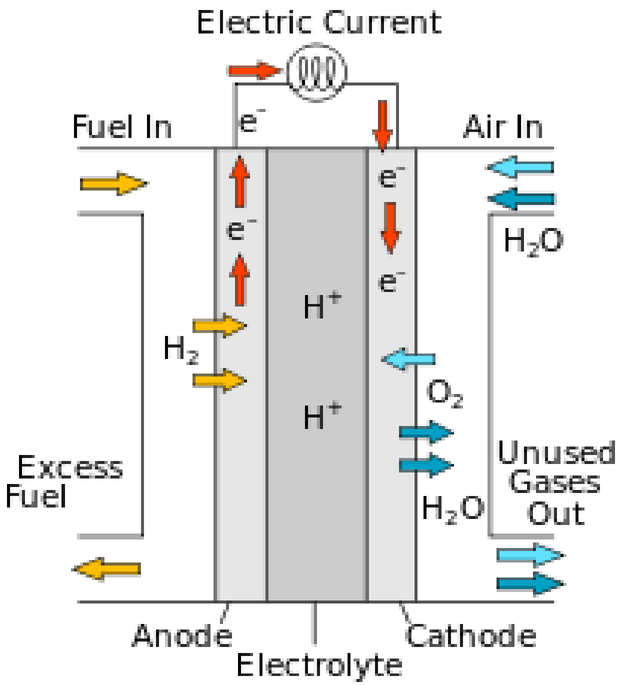
CLOSED CYCLE GAS TURBINE POWER PLANT

In closed cycle gas turbine plant, the working fluid (air or any other suitable gas) coming out from compressor is heated in a heater by an external source at constant pressure. The high temperature and high- pressure air coming out from the external heater is passed through the gas turbine.

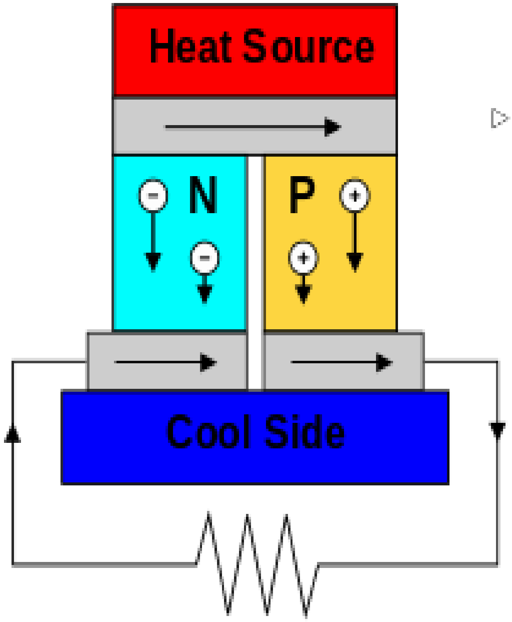


DIRECT ENERGY CONVERSION

- **FUEL CELLS:**



THERMO ELECTRIC SYSTEM:



SOLAR POWER PLANT

- That kind of power plants creates energy by transforming the heat and light from the sun.
- There are Two types:-

➢ **<u>Solar Thermal Energy</u>** :- It stores the heat of the sun, which transforms water into steam, that moves turbines which are connected to a generator that collect energy.

➢ **<u>Photovoltaic Energy</u>** :- Is a method of generating electrical power by converting solar radiation into direct current electricity.

WIND POWER PLANT

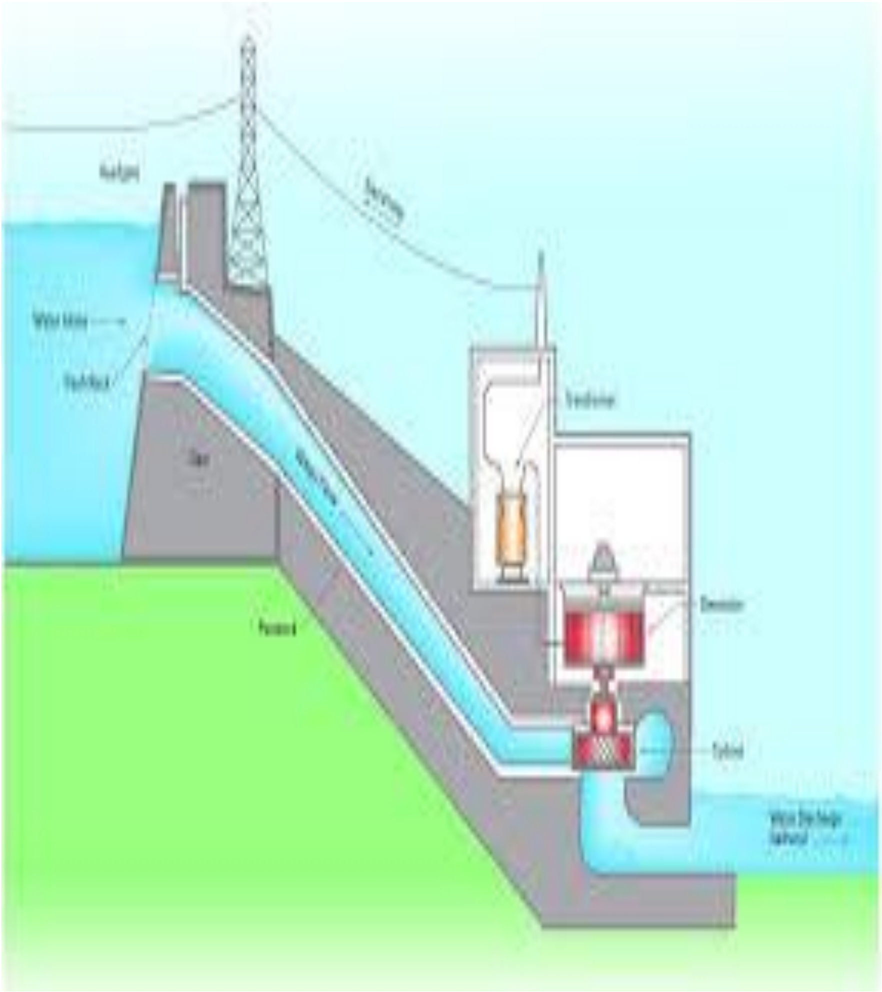
- Wind station are the ones that transform wind energy into another useful kind of energy
- A wind form consist of almost a hundred of winds turbines connected to electric power transmission network

UNIT-III

HYDRO ELECTRIC POWER PLANT

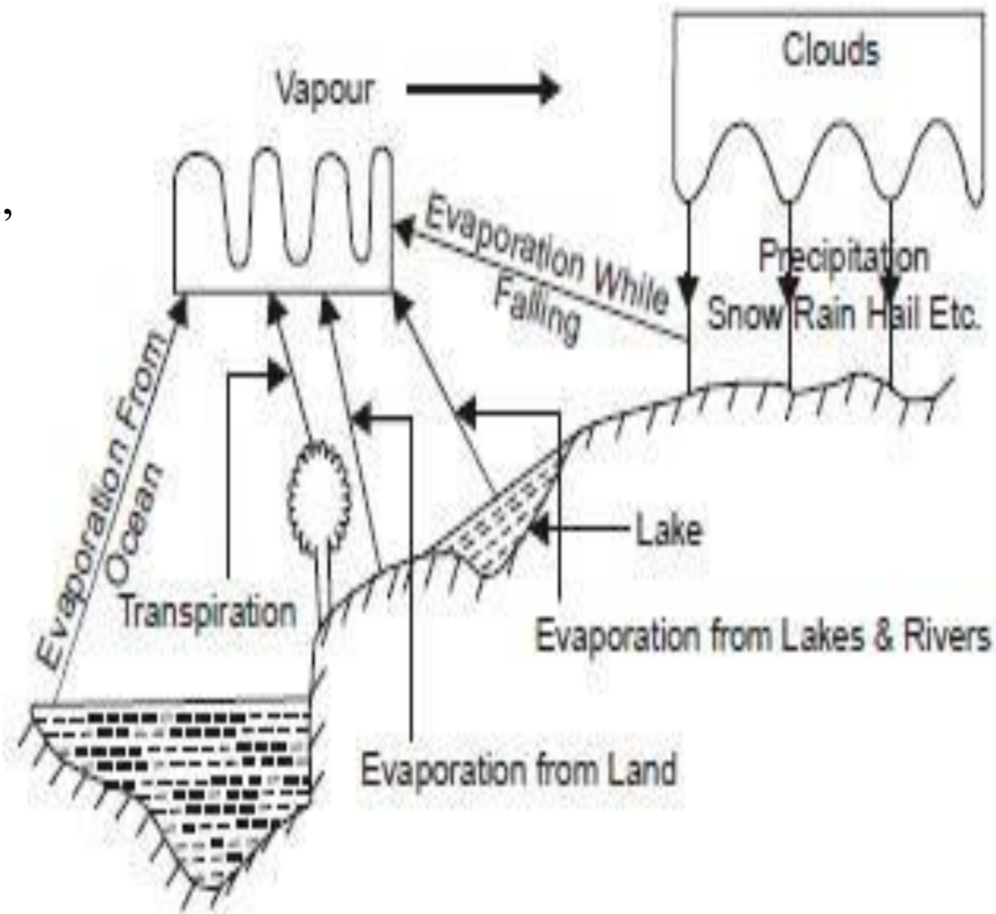
HYDRAULIC POWER PLANT

- The hydroelectric power plants are stations where energy is produced by the force of falling water
- The water moves a turbine connected to a generator that collect the energy that water creates



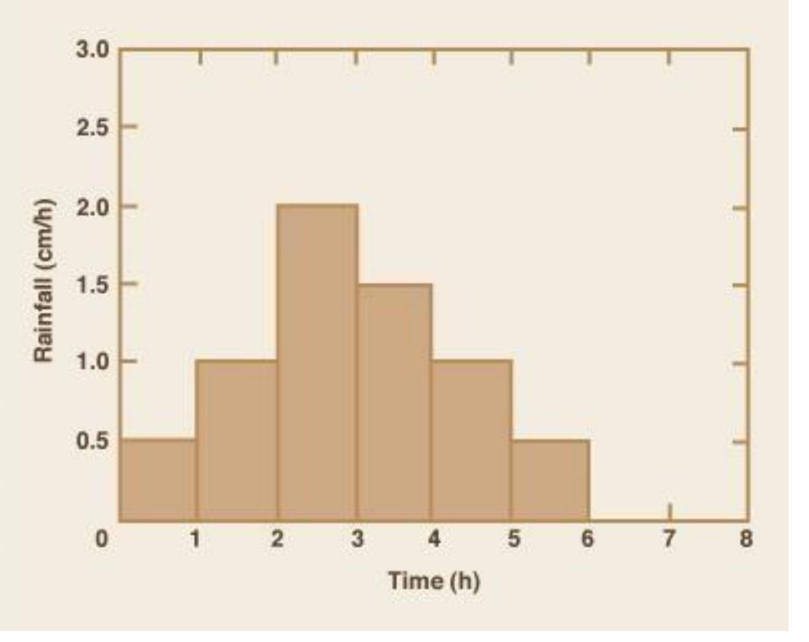
HYDROLOGICAL CYCLE

The generation of electric energy from falling water is only a small process in the mighty heat power cycle known as "Hydrological cycle" or rain evaporation cycle". It is the process by which the moisture from the surface of water bodies covering the earth's surface is transferred to the land and back to the water bodies again. This cycle is shown in Fig.3.1. The input to this cycle is the solar energy.



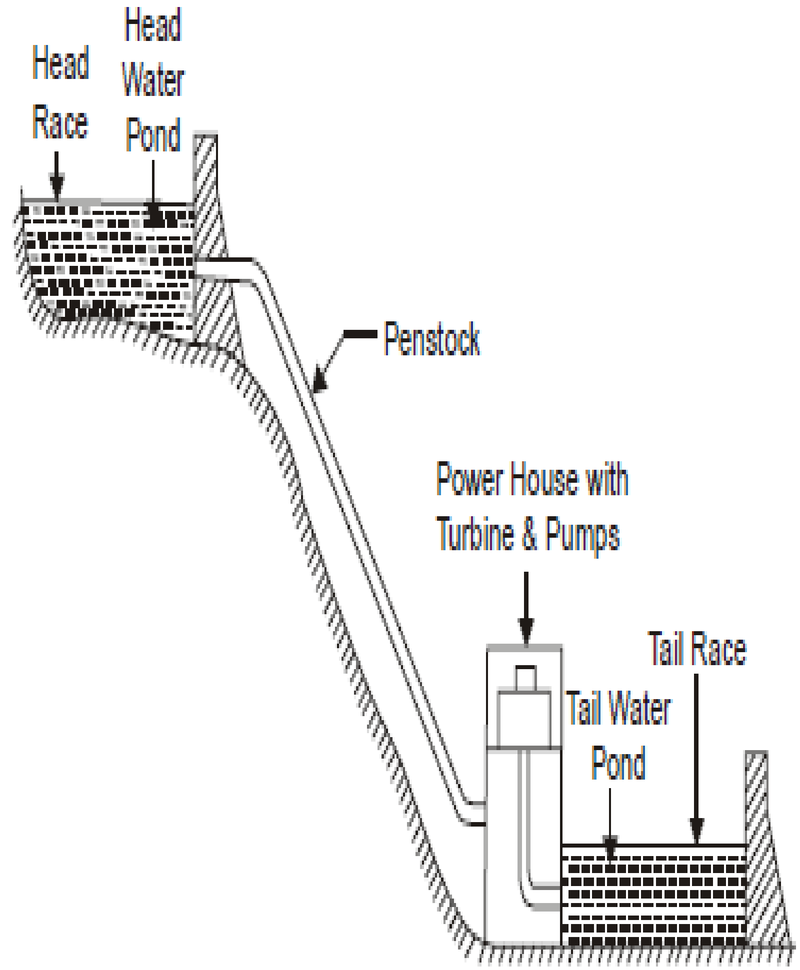
HYDROGRAPH:

A hydrograph indicates the variation of discharge or flow with time. It is plotted with flows as ordinates and time intervals as abscissas. The flow is in m3/sec and the time may be in hours, days, weeks or months.



PUMPED STORAGE PLANTS:

- These plants supply the peak load for the base load power plants and pump all or a portion of their own water supply. The usual construction would be a tail water pond and a head water pond connected through a penstock.



TYPES OF DAMS:

- MASANORY DAMS

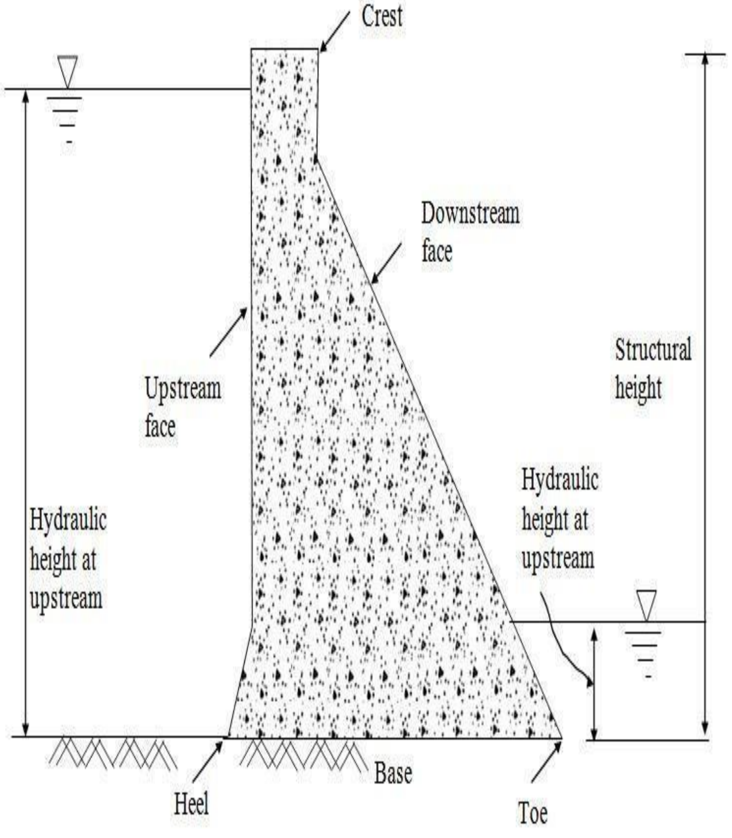
- Solid gravity dams
- Buttress dams
- Arch dams

- EARTHFILL DAMS

- Earth fill dams
- Rock fill dams

SOLID GRAVITY DAMS:

A gravity dam is one which depends entirely on its own mass for stability. The basic gravity profile is triangular in shape, but for practical purposes, is modified at the top.



TYPES OF SPILLWAYS:

- Overflow spillway
- Chute spillway
- Shaft spillway
- Siphon spillway

Overflow spillway:

Open channel spillways are Dam spillways that utilize the principles of open-channel flow to convey impounded water in order to prevent dam failure. They can function as principal spillways, emergency spillways, or both. They can be located on the dam itself or on a natural grade in the vicinity of the dam.

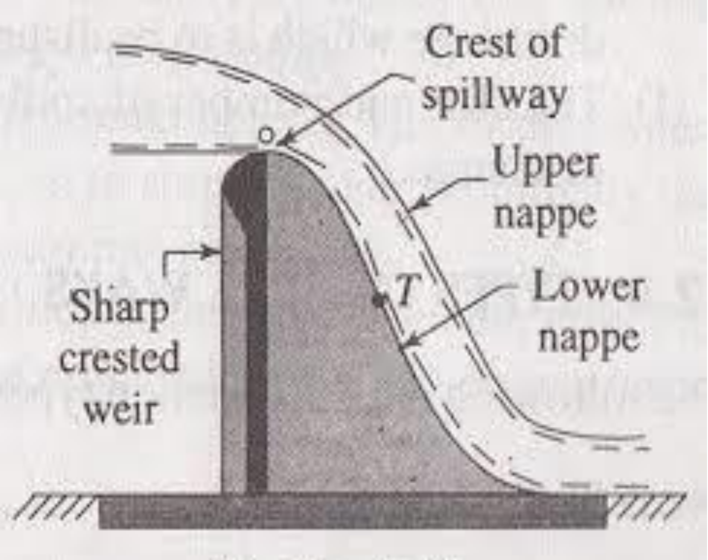


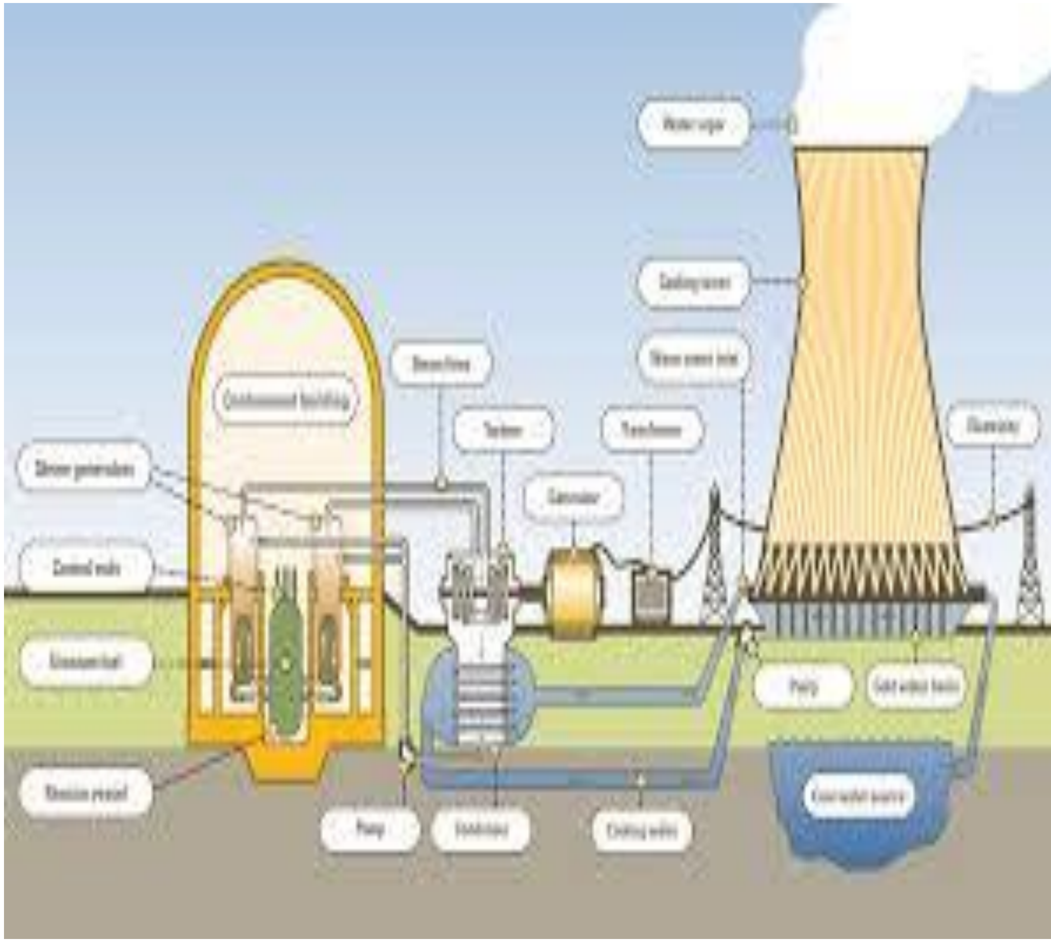
Fig: Ogee Spillway

UNIT-IV

NUCLEAR POWER STATION

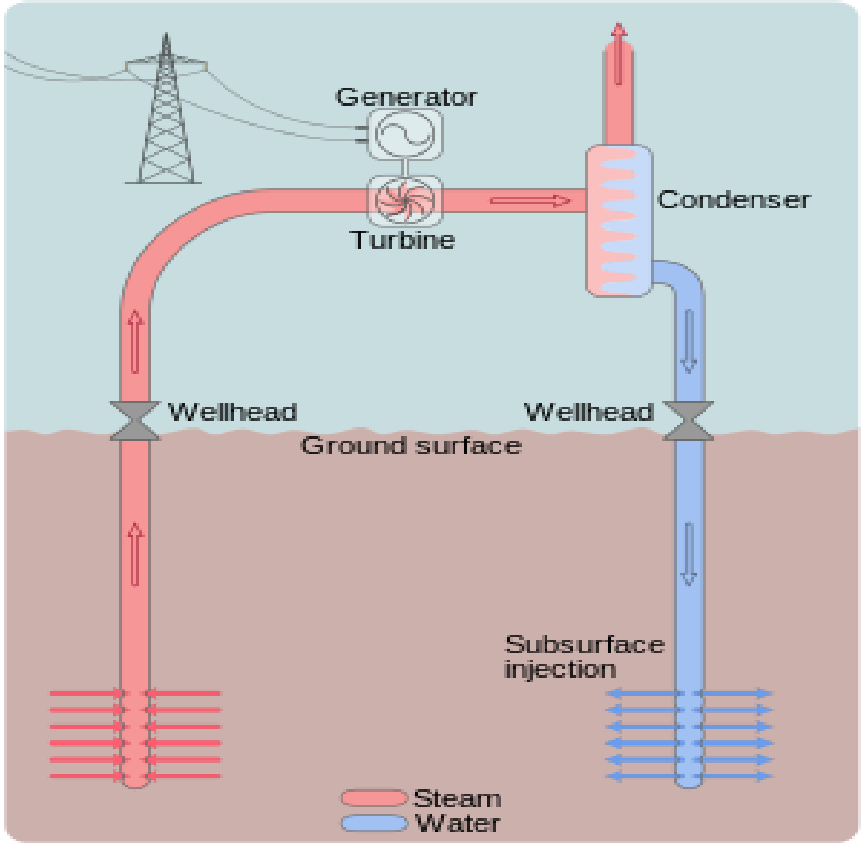
Nuclear Thermal Power Plant

- The heat is produced by fission in a nuclear reactor (a light water reactor). Directly or indirectly, water vapour (steam) is produced. The pressurized steam is then usually fed to a multi-stage steam turbine.



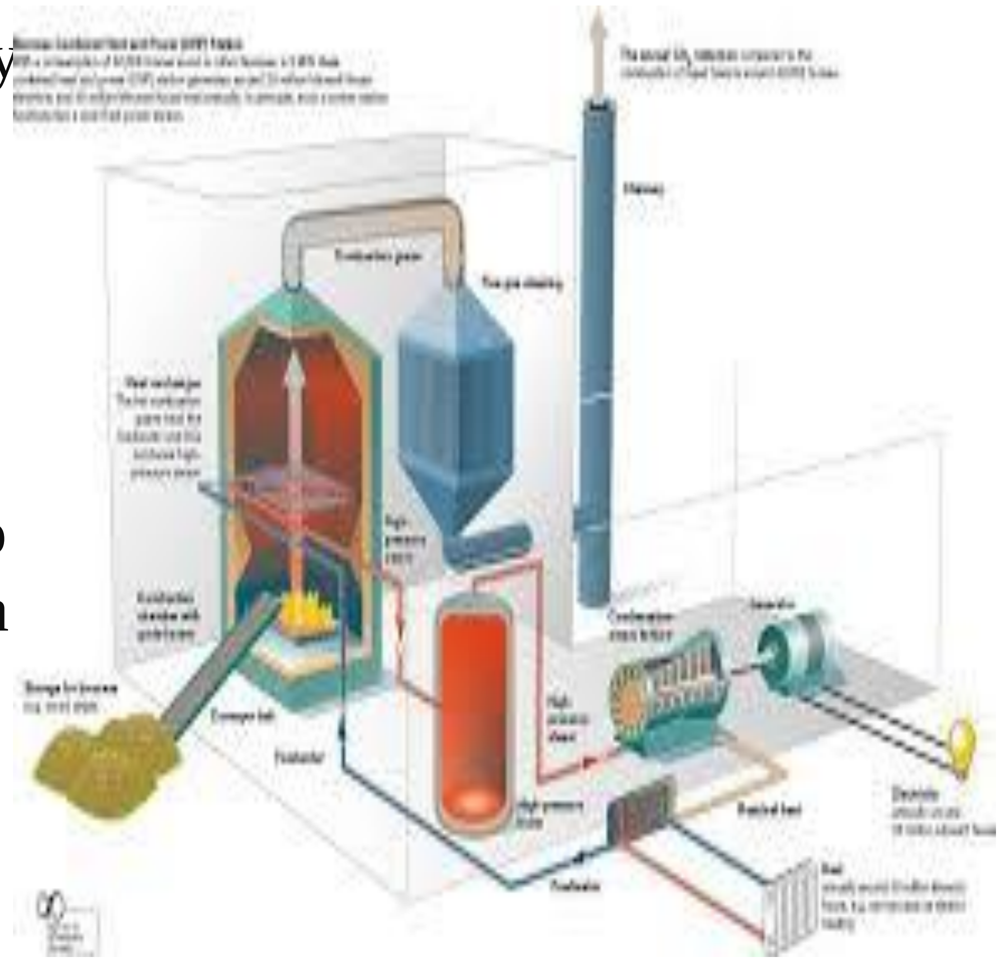
Geothermal Power Plant

- Geothermal electricity is electricity generated from geothermal energy. Technologies in use include dry steam power plants, flash steam power plants and binary cycle power plants.

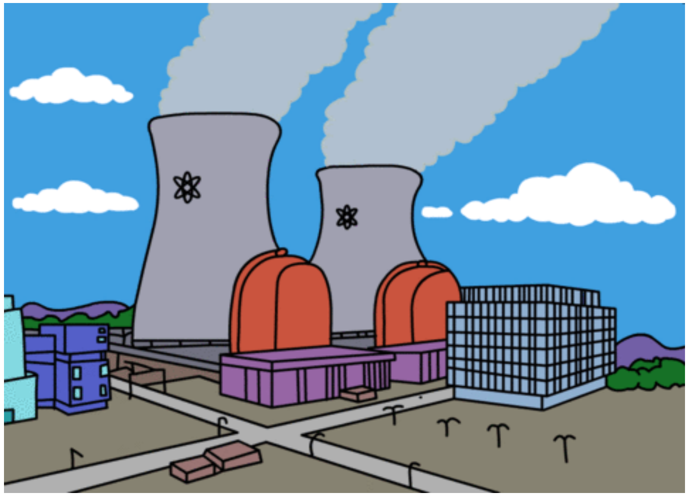


BIOMASS POWER PLANT

- The Biomass thermal energy consist in buring the natural waste and rubbish, such as plants animals, food.
- It produces natural gases that provides heat to water and which transforms it into steam, that later will move a turbine connected to a generator that collects energy



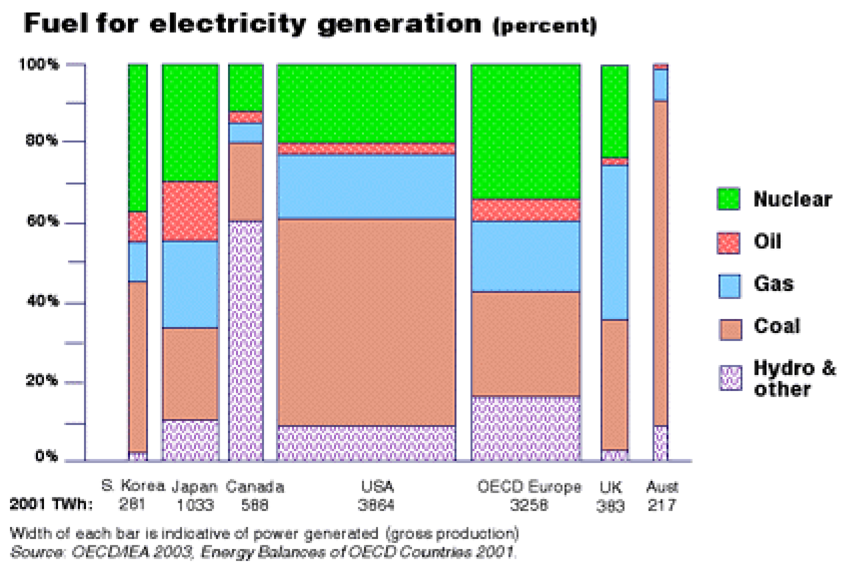
Nuclear Power – Need and Future



Outline

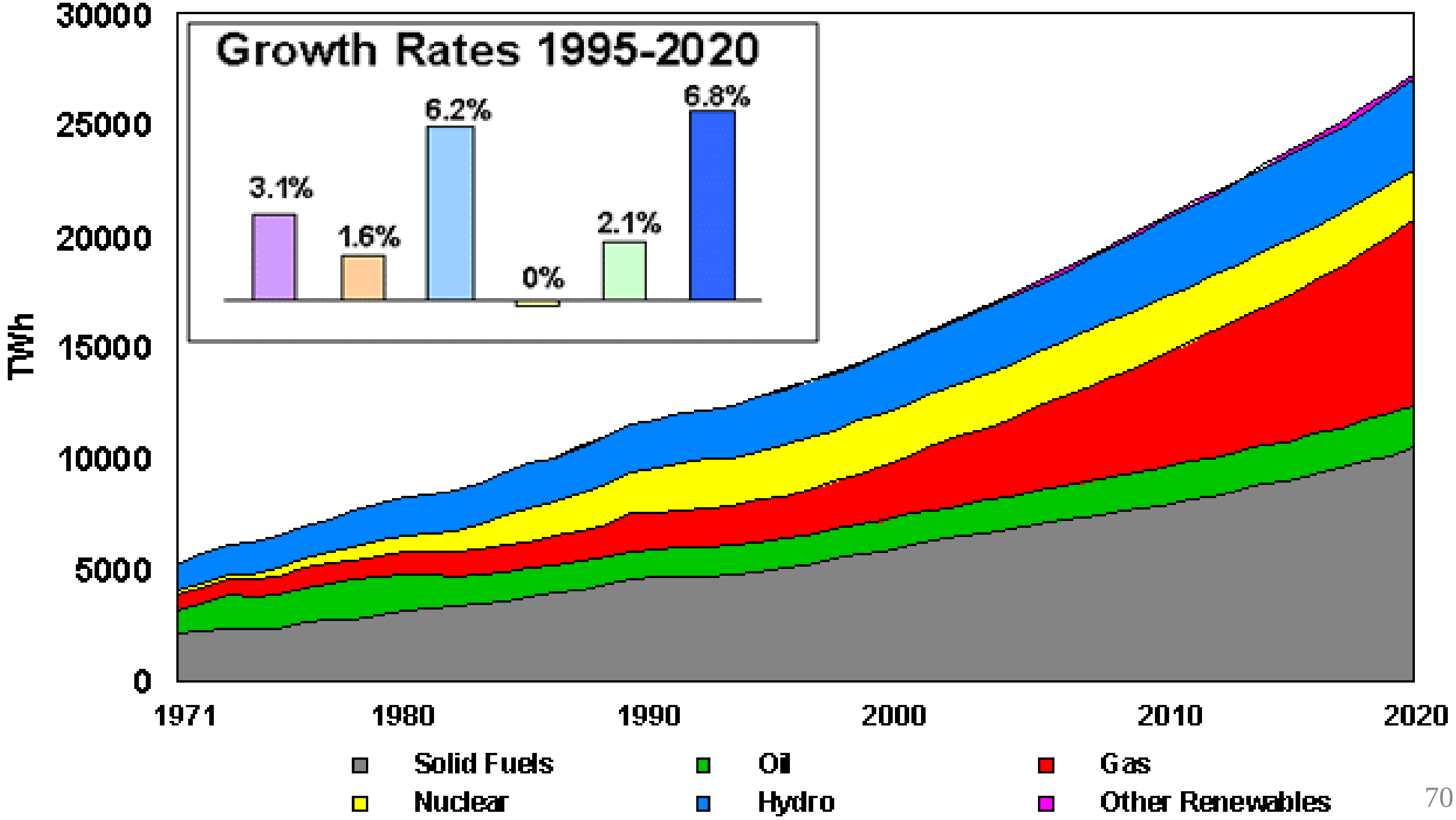
- Economics of Nuclear Energy
- Basics of a Power Plant
- Heat From Fission
- History of Nuclear Power
- Current Commercial Nuclear R Designs
- Nuclear Fuel Cycle
- Future Reactor Designs
- Policy Issues
- Conclusions

Current World Demand for Electricity

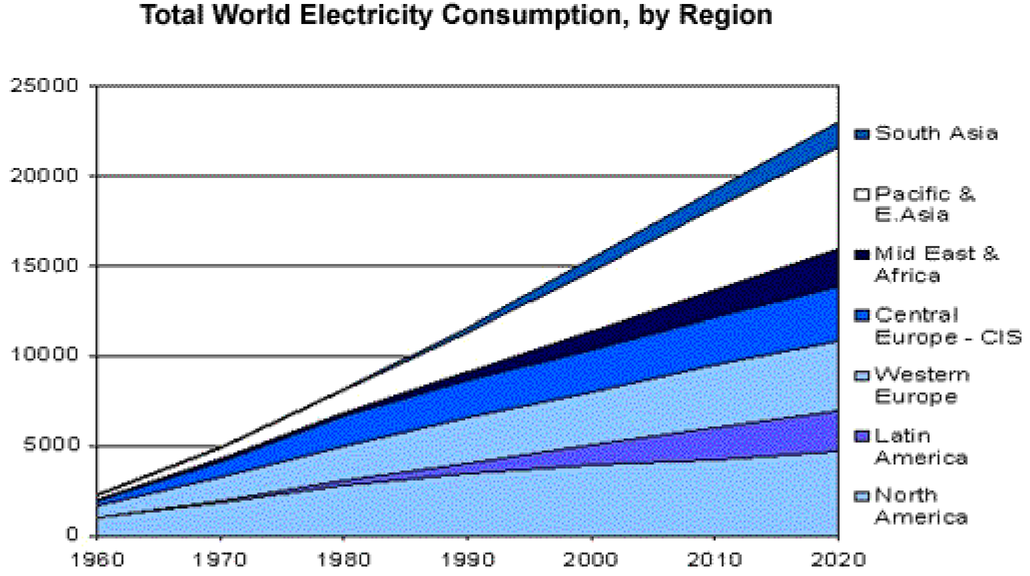


Future Demand

Projected changes in world electricity generation by fuel, 1995 to 2020

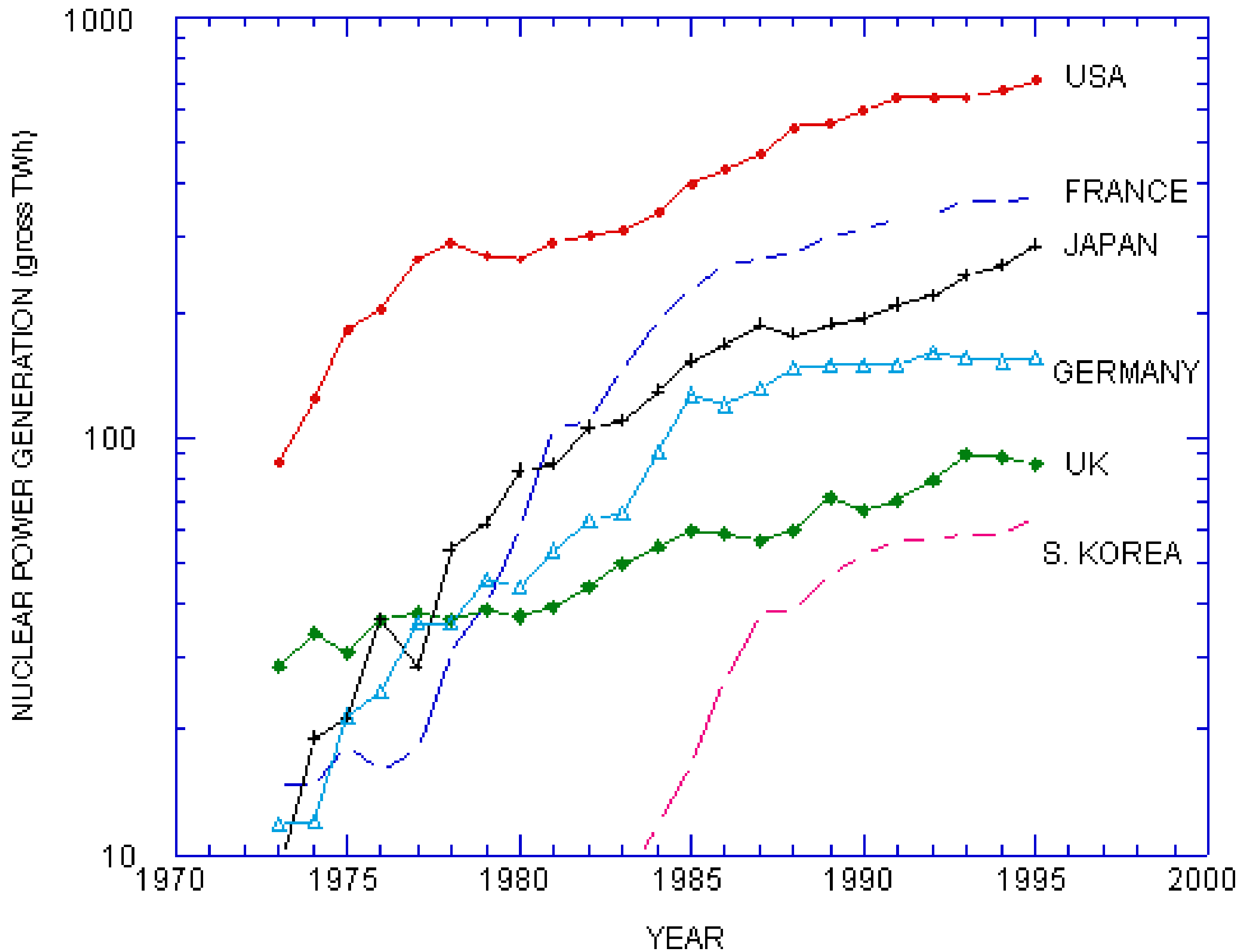


World Demand for Power

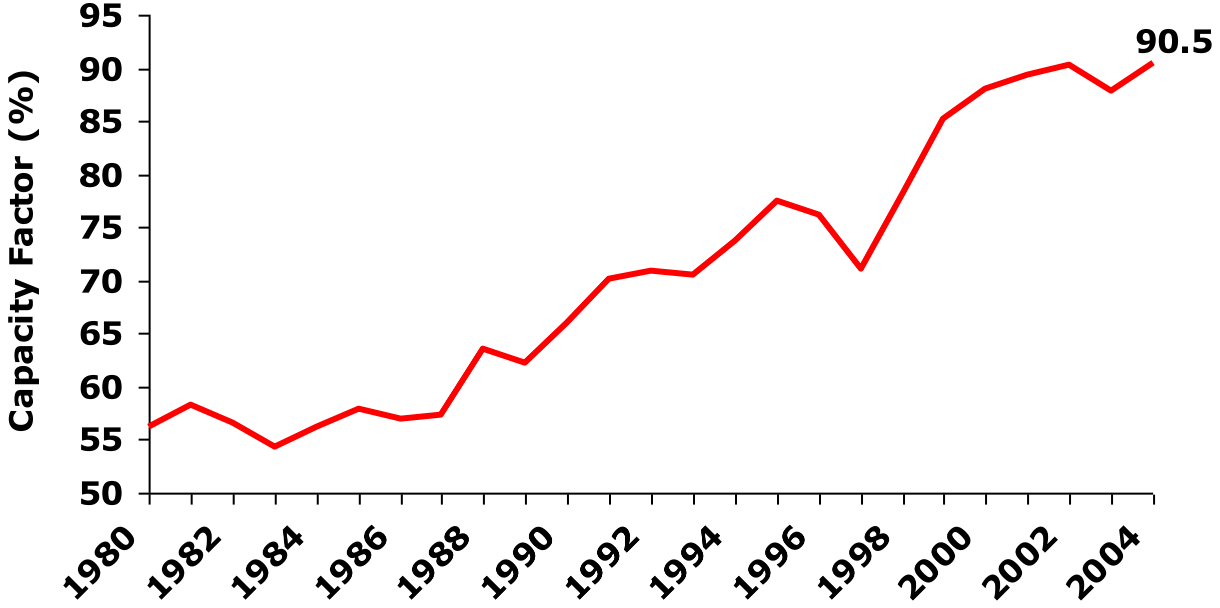


Source: World Energy Council 1993. Projection to 2020 is Reference Case (total: 13.4 Gtoe, compared with Modified Reference 16.0 Gtoe. High Growth 17.2 Gtoe and Ecologically-driven 11.3 Gtoe cases

Past Demand by Country

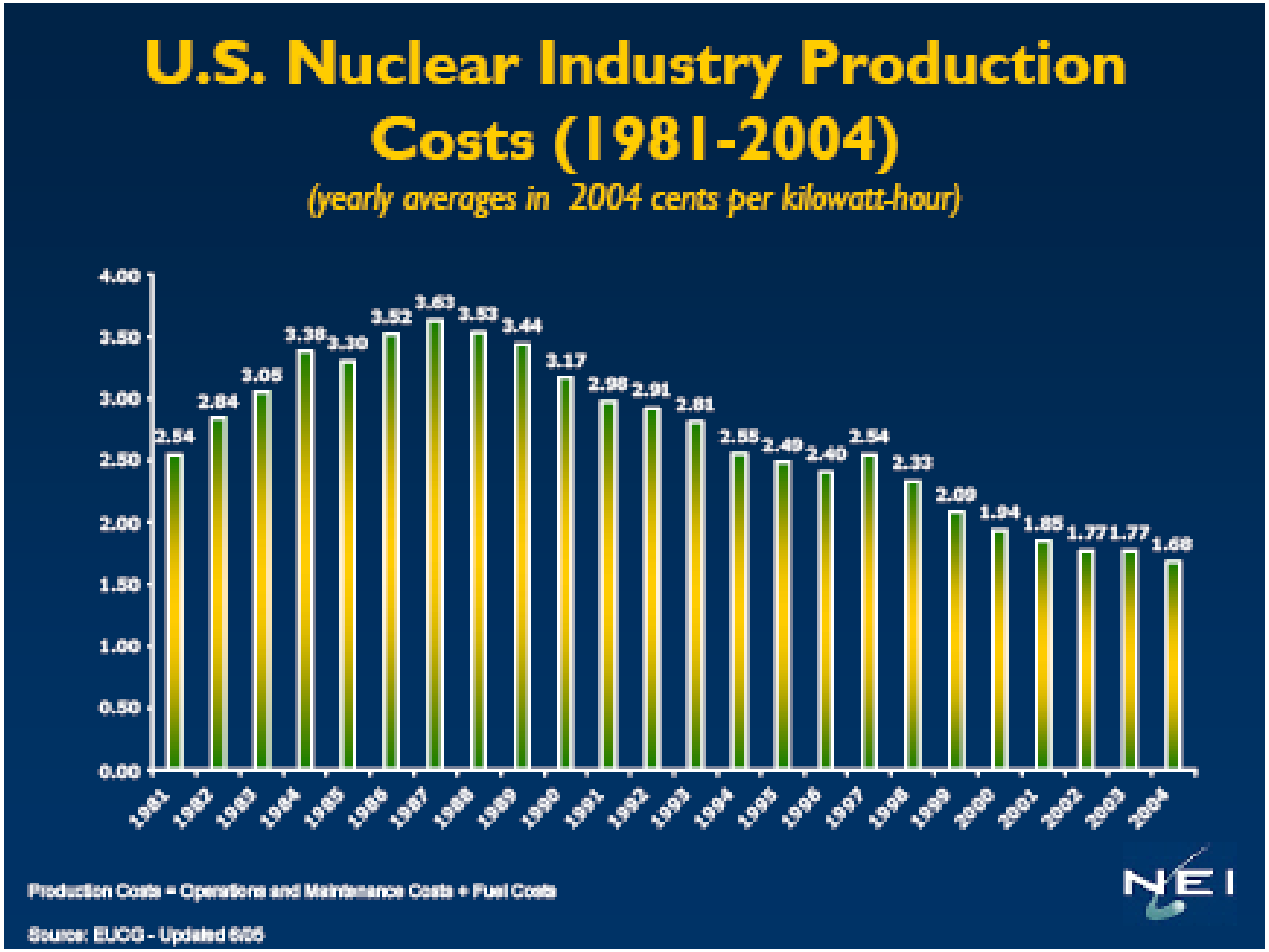


U.S. Nuclear Plant Capacity Factors



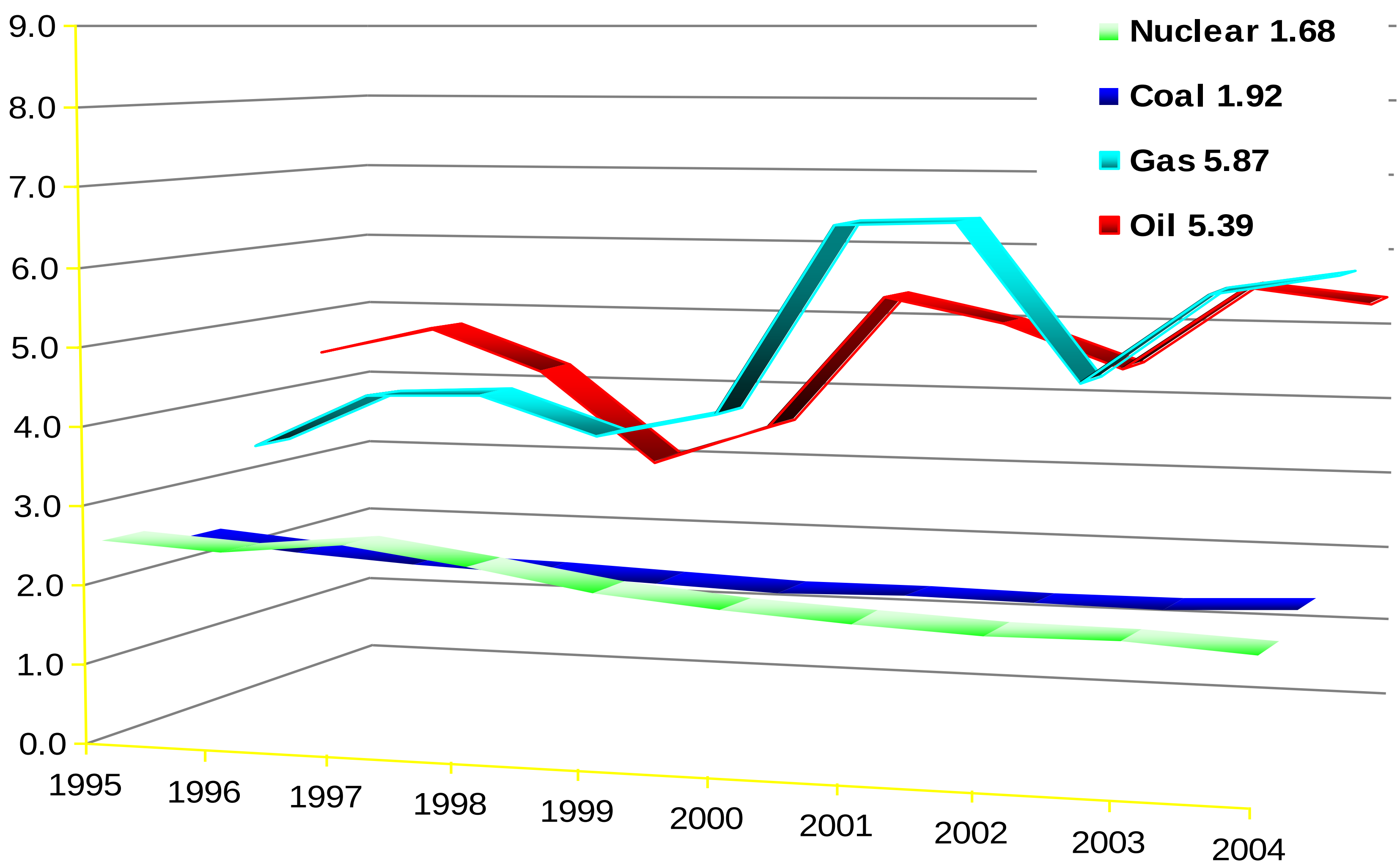
http://www.nei.org/

U.S. Nuclear Production Costs



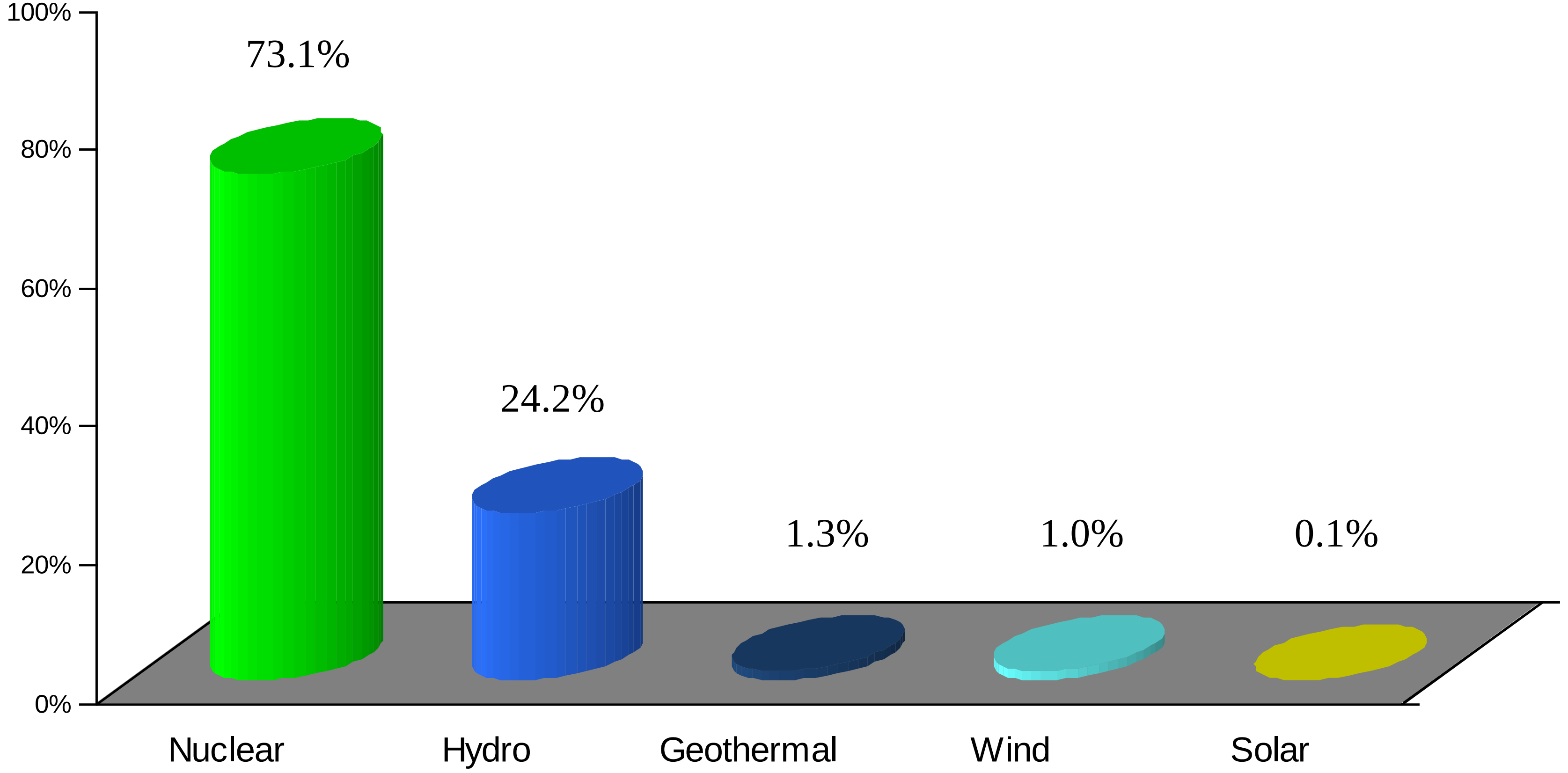
U.S. Electricity Production Costs

(in constant 2004 cents/kWh)



Source: Energy Velocity / EUCG

Emission-Free Sources of Electricity

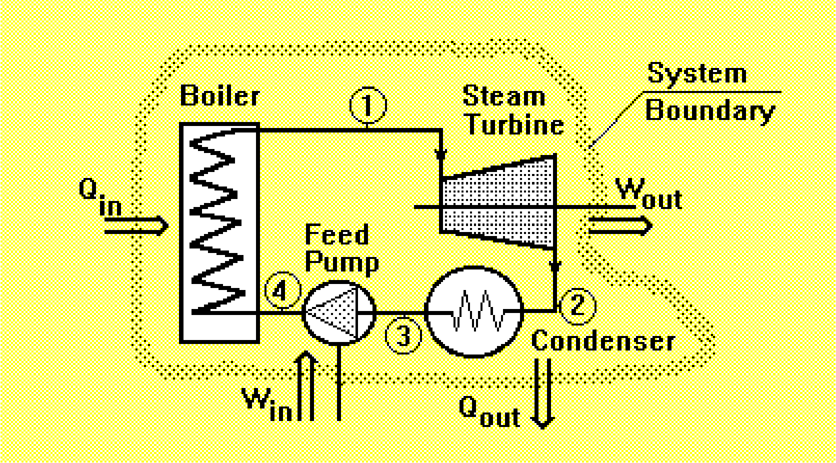


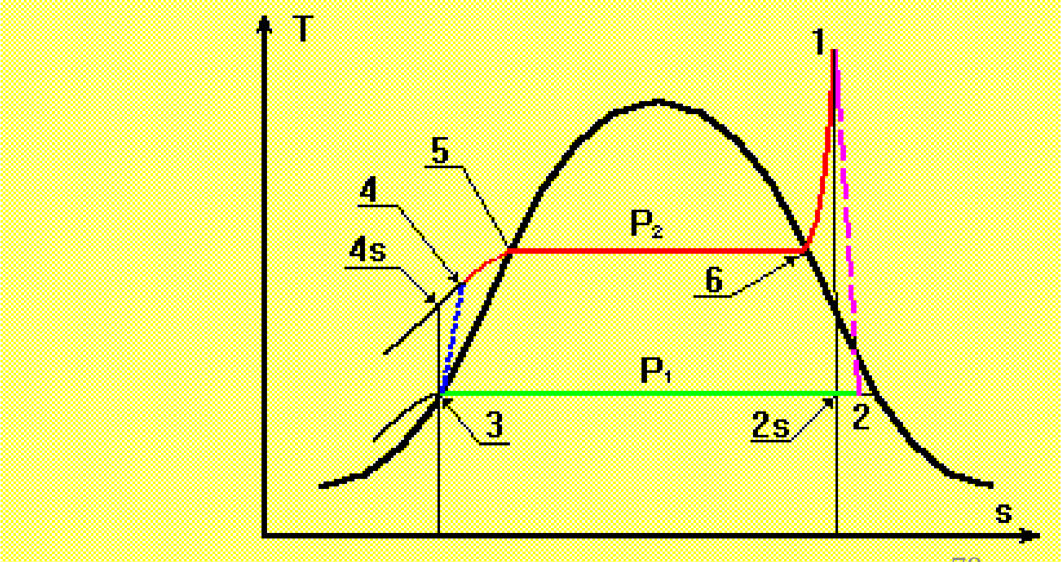
Source: Energy Information Administration

Basics of a Power Plant

- The basic premises for the majority of power plants is to:
  - 1) Create heat
  - 2) Boil Water
  - 3) Use steam to turn a turbine
  - 4) Use turbine to turn generator
  - 5) Produce Electricity
- Some other power producing technologies work differently (e.g., solar, wind, hydroelectric, …)

Nuclear Power Plants use the Rankine Cycle

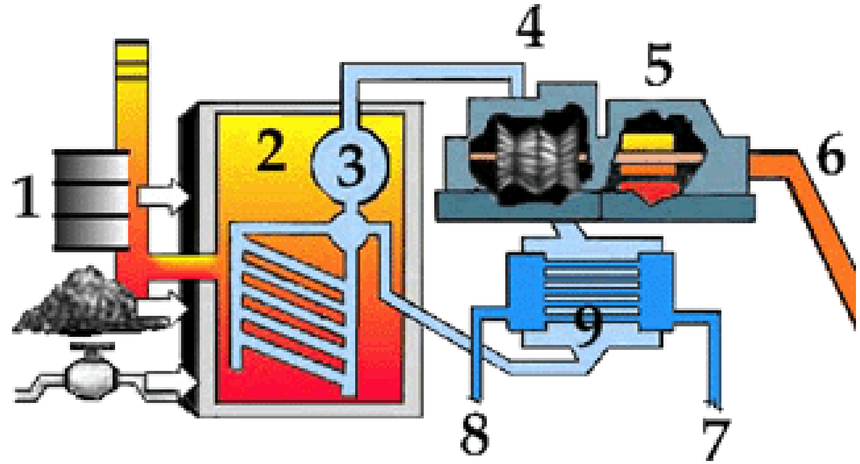


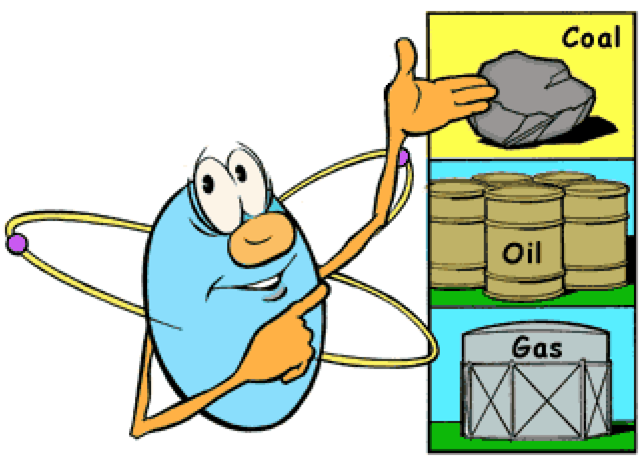


T-s diagram for a Rankine cycle.

Create Heat

- Heat may be created by:
  - Burning coal
  - Burning oil
  - Other combustion
  - Nuclear fission

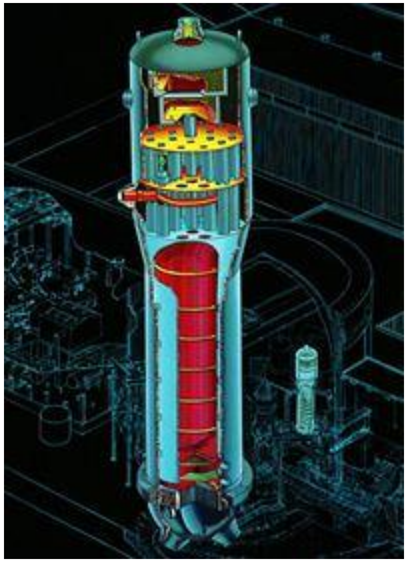




1) oil, coal or gas
2) heat
3) steam
4) turbine
5) generator
6) electricity
7) cold water
8) waste heat water
9) condenser

Boil Water

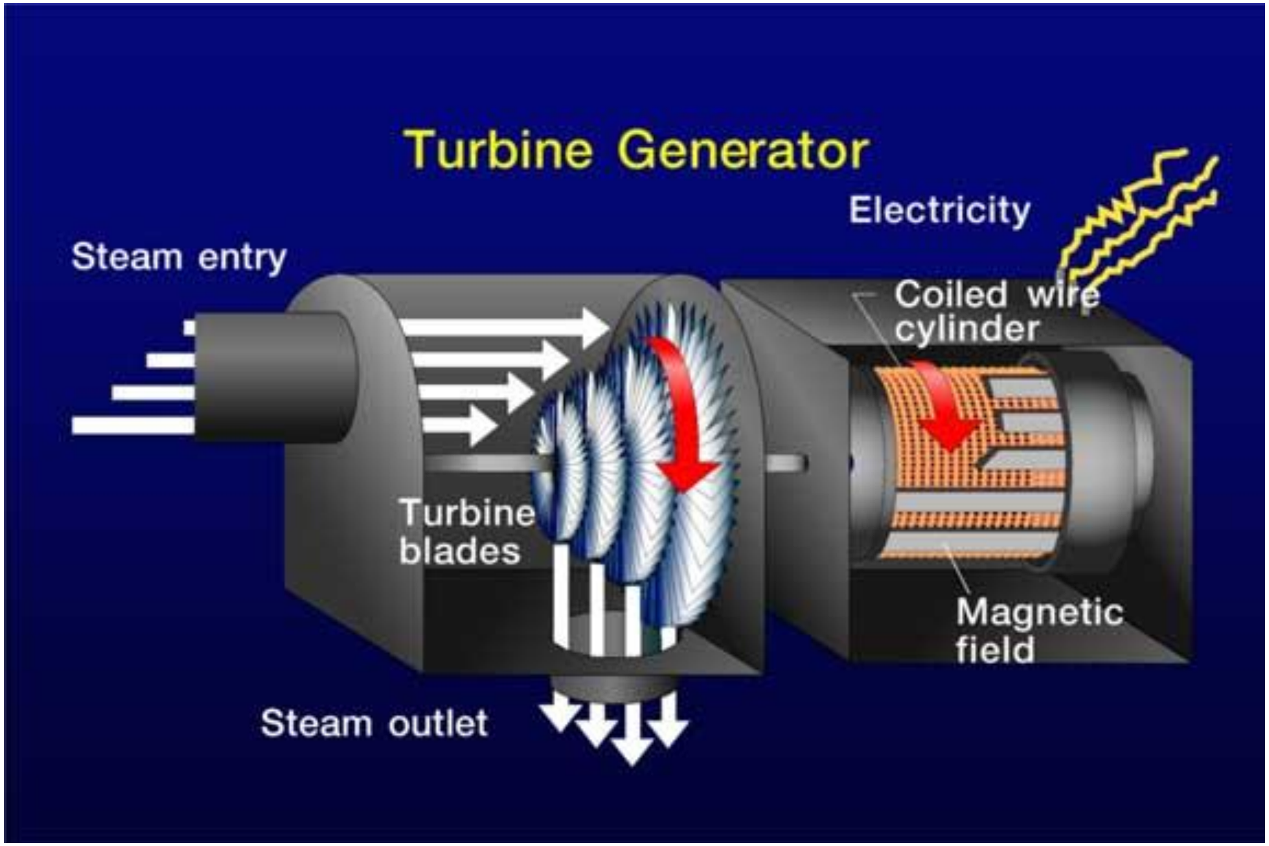
- The next process it to create steam.
- The steam is necessary to turn the turbine.



Westinghouse Steam Generator

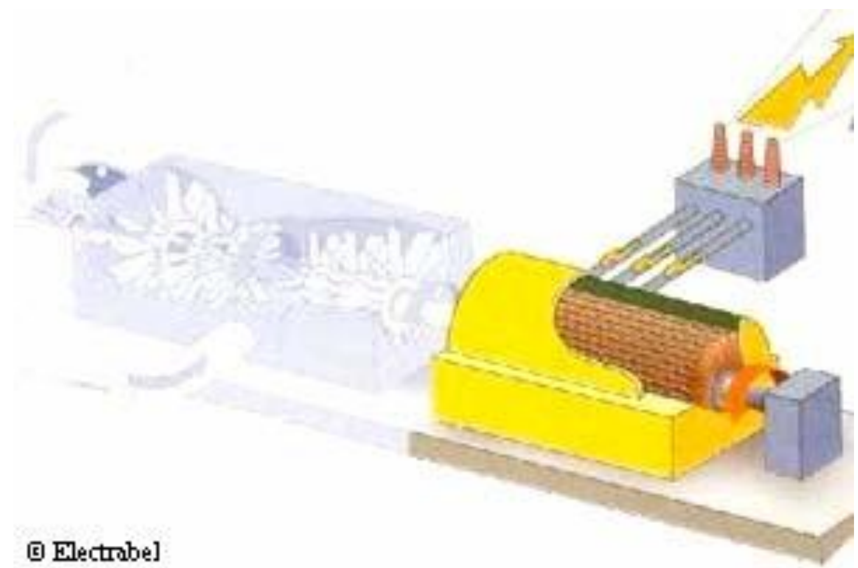
Turbine

- Steam turns the turbine.



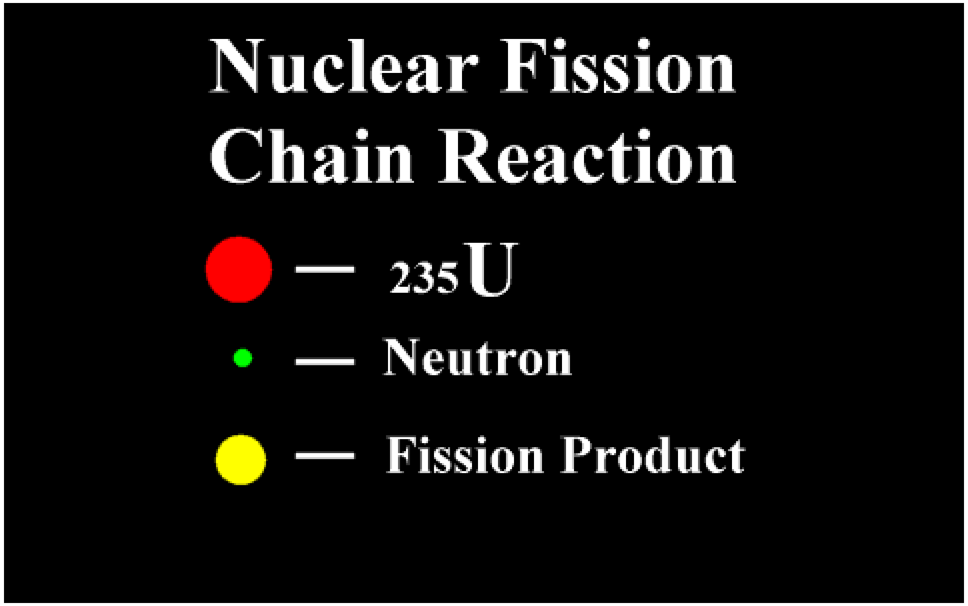
Generator

- As the generator is turned, it creates electricity.



Heat From Fission

Fission Chain Reaction



Nuclear History

- **1939.** Nuclear fission discovered.
- **1942.** The world´s first nuclear chain reaction takes place in Chicago as part of the wartime Manhattan Project.
- **1945.** The first nuclear weapons test at Alamagordo, New Mexico.
- **1951.** Electricity was first generated from a nuclear reactor, from EBR-I (Experimental Breeder Reactor-I) at the National Reactor Testing Station in Idaho, USA. EBR-I produced about 100 kilowatts of electricity (kW(e)), enough to power the equipment in the small reactor building.
- **1970s.** Nuclear power grows rapidly. From 1970 to 1975 growth averaged 30% per year, the same as wind power recently (1998-2001).
- **1987.** Nuclear power now generates slightly more than 16% of all electricity in the world.
- **1980s.** Nuclear expansion slows because of environmentalist opposition, high interest rates, energy conservation prompted by the 1973 and 1979 oil shocks, and the accidents at Three Mile Island (1979, USA) and Chernobyl (1986, Ukraine, USSR).
- **2004**. Nuclear power´s share of global electricity generation holds steady around 16% in the 17 years since 1987.

Current Commercial Nuclear Reactor Designs

- Pressurized Water Reactor (PWR)
- Boiling Water Reactor (BWR)
- Gas Cooled Fast Reactor
- Pressurized Heavy Water Reactor (CANDU)
- Light Water Graphite Reactor (RBMK)
- Fast Neutron Reactor (FBR)

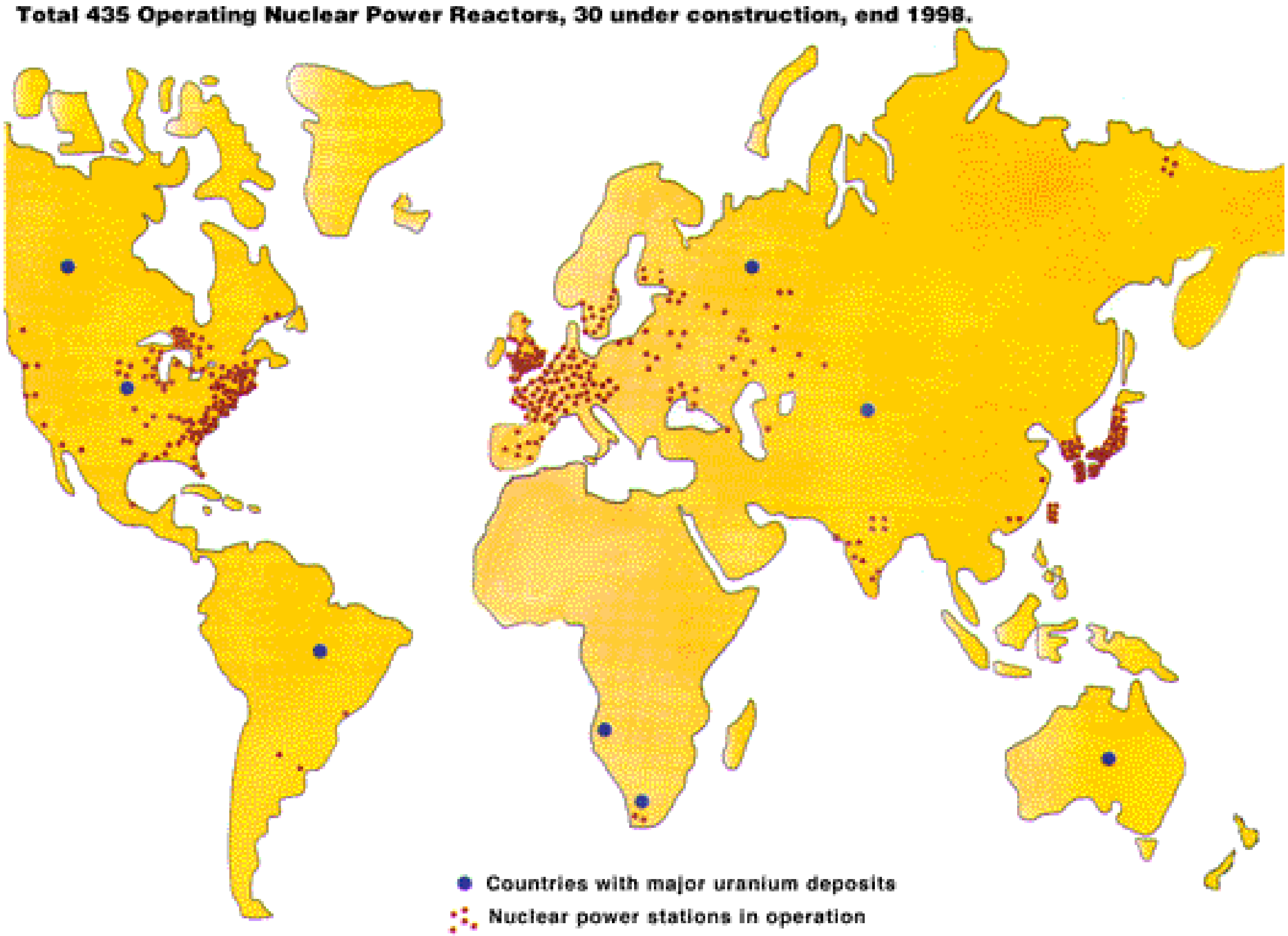
The Current Nuclear Industry

Nuclear power plants in commercial operation

Reactor Type	**Main Countries**	**Number**	**GWe**	**Fuel**	**Coolant**	**Moderator**
Pressurised Water Reactor (PWR)	US, France, Japan, Russia	252	235	enriched UO_2	water	water
Boiling Water Reactor (BWR)	US, Japan, Sweden	92	83	enriched UO_2	water	water
Gas-cooled Reactor (Magnox & AGR)	UK	34	13	natural U (metal), enriched UO_2	CO_2</SUB	graphite
Pressurised Heavy Water Reactor "CANDU" (PHWR)	Canada	33	18	natural UO_2	heavy water	heavy water
Light Water Graphite Reactor (RBMK)	Russia	14	14.6	enriched UO_2	water	graphite
Fast Neutron Reactor (FBR)	Japan, France, Russia	4	1.3	$PUO_2$and UO_2	liquid sodium	none
other	Russia, Japan	5	0.2			
	TOTAL	434	365			

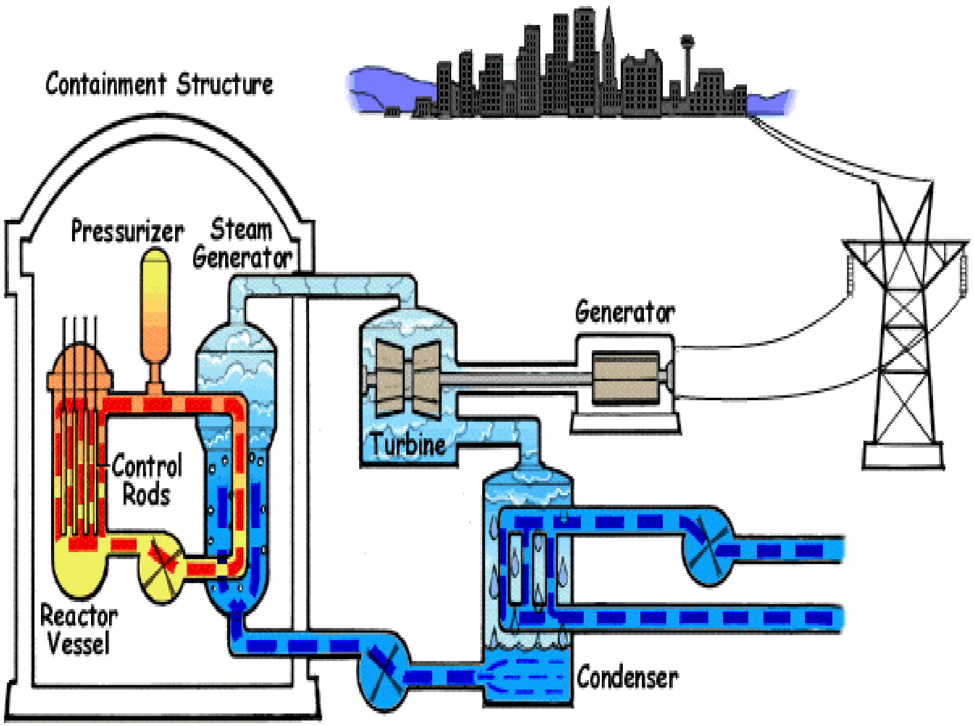
Source: Nuclear Engineering International handbook 1999, but including Pickering A in Canada.

Nuclear Reactors Around the World



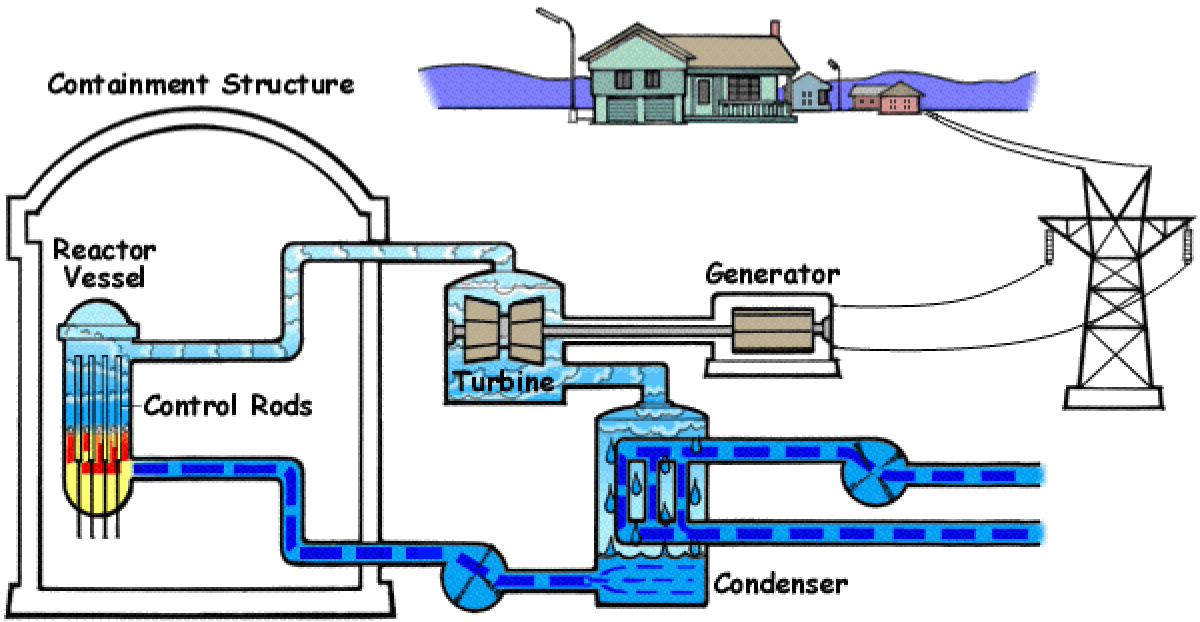
PWR

The most widely used reactor type in the world is the Pressurized Water Reactor (PWR) which uses enriched (about 3.2% U235) uranium dioxide as a fuel in zirconium alloy cans. The fuel, which is arranged in arrays of fuel “pins” and interspersed with the movable control rods, is held in a steel vessel through which water at high pressure (to suppress boiling) is pumped to act as both a coolant and a moderator.



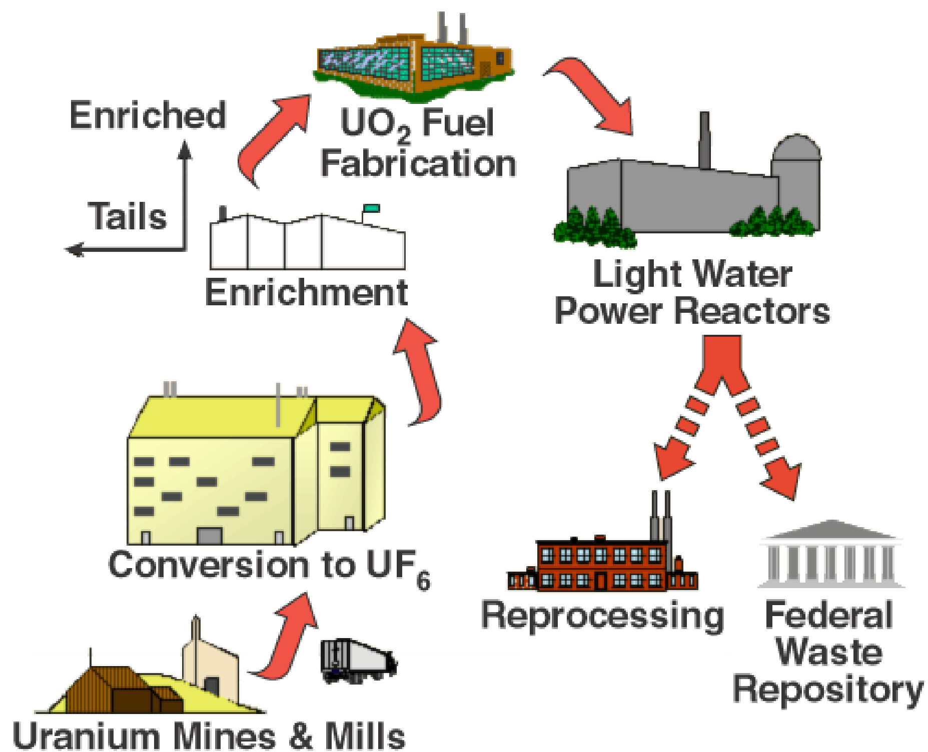
BWR

The second type of water cooled and moderated reactor does away with the steam generator and, by allowing the water within the reactor circuit to boil, it raises steam directly for electrical power generation.

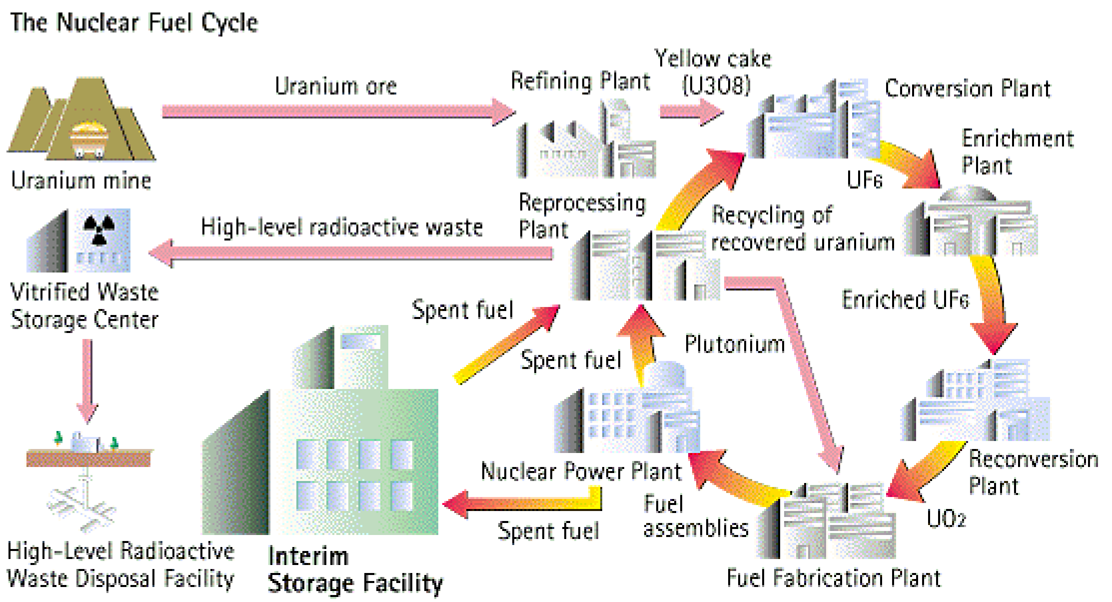


Nuclear Fuel Cycle

- Uranium Mining and Milling
- Conversion to UF_6
- Enrichment
- Fuel Fabrication
- Power Reactors
- Waste repository



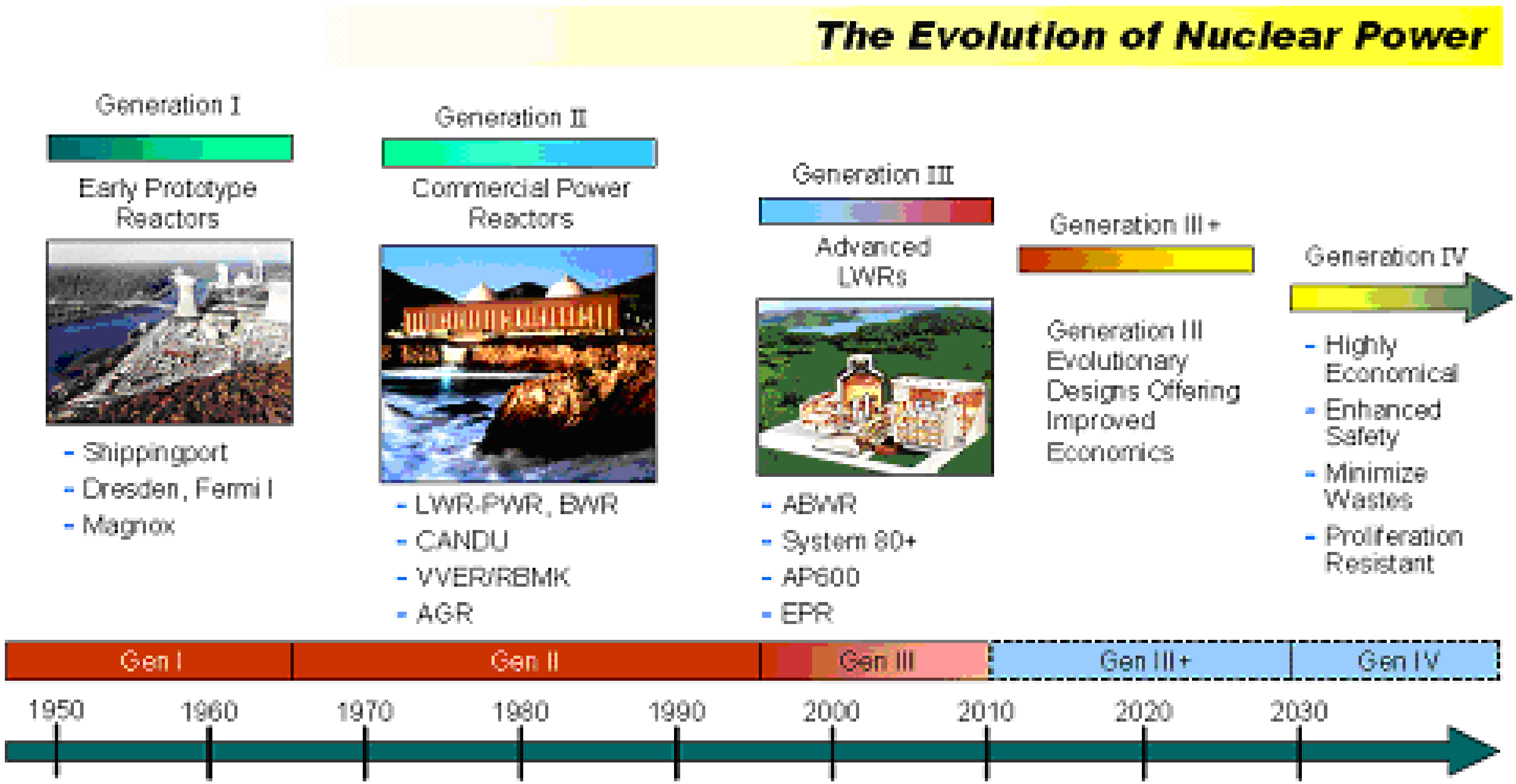
Nuclear Fuel Cycle with Reprocessing



Future Reactor Designs

- Research is currently being conducted for design of the next generation of nuclear reactor designs.
- The next generation designs focus on:
  - Proliferation resistance of fuel
  - Passive safety systems
  - Improved fuel efficiency (includes breeding)
  - Minimizing nuclear waste
  - Improved plant efficiency (*e.g.*, Brayton cycle)
  - Hydrogen production
  - Economics

Future Reactor Designs (cont.)

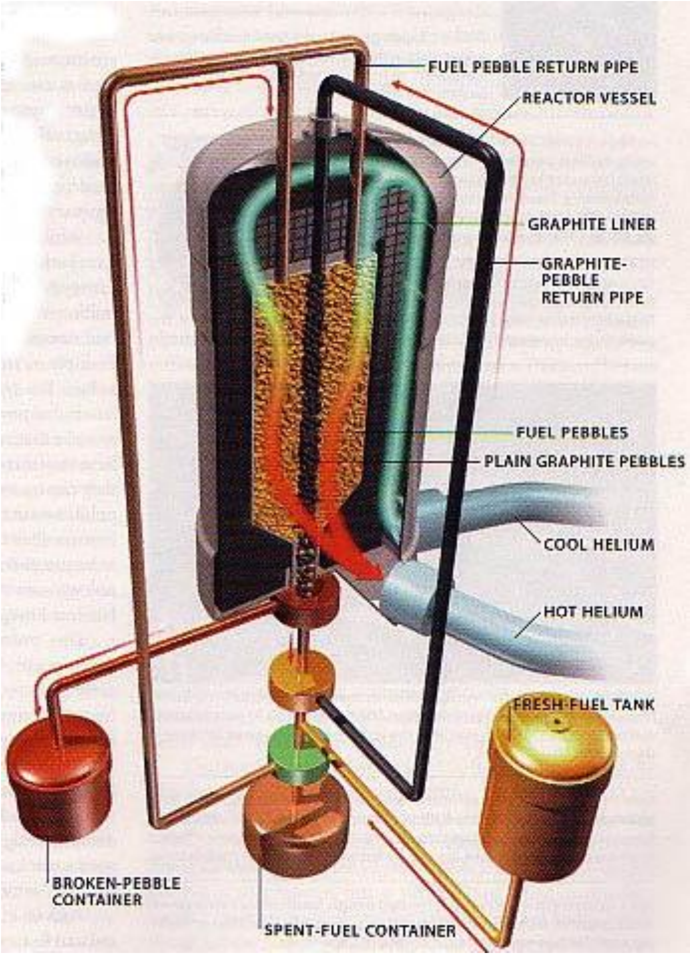


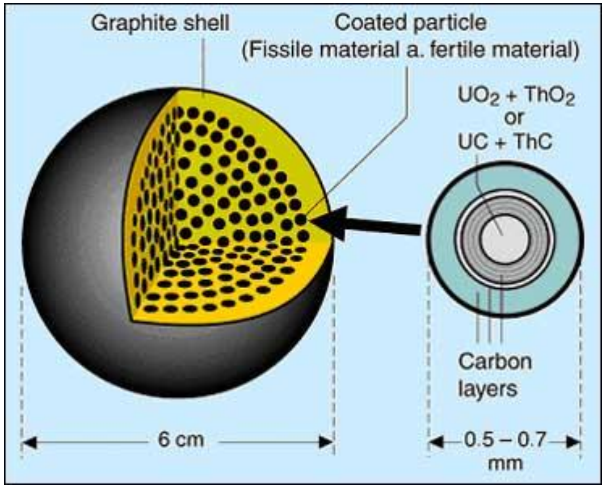
Generation III Reactor Designs

- Pebble Bed Reactor
- Advanced Boiling Water Reactor (ABWR)
- AP600
- System 80+

Pebble Bed Reactor

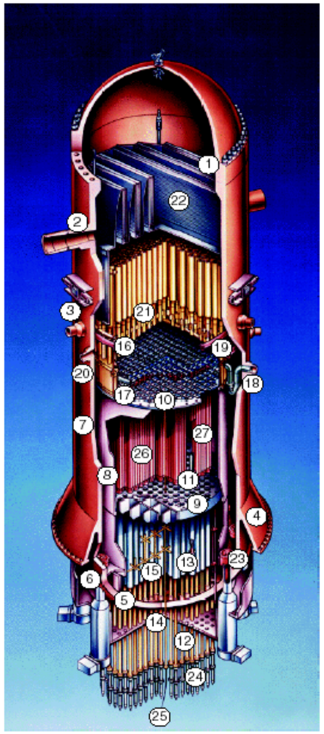
- No control rods.
- He cooled
- Use of the fuel cycle





Advanced Boiling Water Reactor (ABWR)

- More compact design cuts construction costs and increases safety.
- Additional control rod power supply improves reliability.
- Equipment and components designed for ease of maintenance.
- Two built and operating in Japan.



1 - Vessel flange and closure head
2 - Steam outlet flow restrictor
3 - Feedwater nozzle
4 - Vessel support skirt
5 - Vessel bottom head
6 - RIP penetrations
7 - Forged shell rings
8 - Core shroud
9 - Core plate
10 - Top guide
11 - Fuel supports
12 - Control rod drive housings
13 - Control rod guide tubes
14 - In-core housing
15 - In-core instrument guide tubes
16 - Feedwater sparger
17 - High pressure core flooder (HPCF) sparger
18 - HPCF coupling
19 - Low pressure flooder (LPFL)
20 - Shutdown cooling outlet
21 - Shroud head and steam separator assembly
22 - Steam dryer assembly
23 - Reactor internal pumps (RIP)
24 - Fine motion control rod drives
25 - Local power range monitor
26 - Fuel assemblies
27 - Control rods

Figure 3-1. ABWR Reactor Assembly

Gen IV Reactors

- Themes in Gen IV Reactors
- Gas Cooled Fast Reactor (GFR)
- Very High Temperature Reactor (VHTR)
- Supercritical Water Cooled Reactor (SCWR)
- Sodium Cooled Fast Reactor (SFR)
- Lead Cooled Fast Reactor (LFR)
- Molten Salt Reactor (MSR)

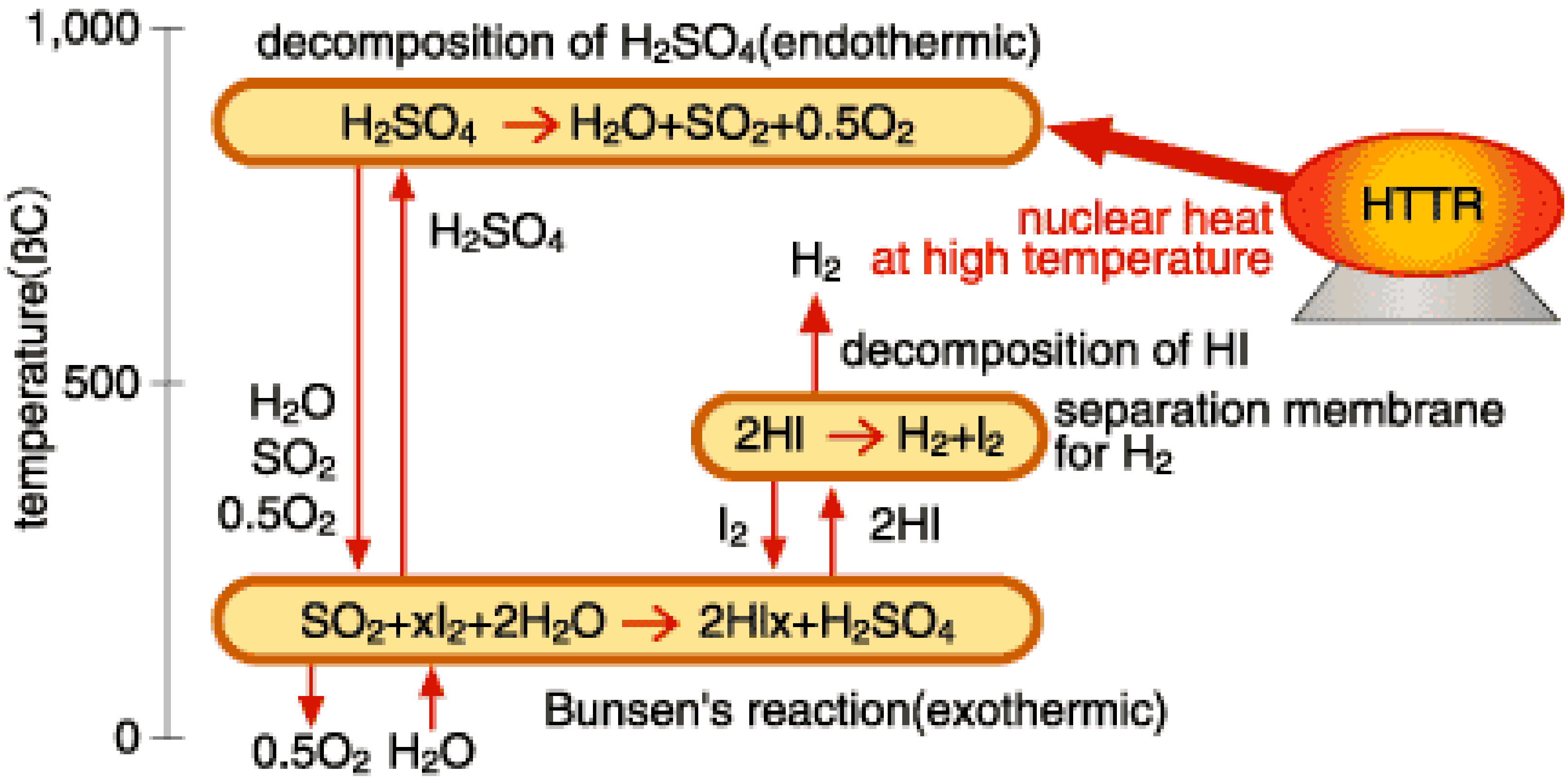
Themes in Gen IV Reactors

- Hydrogen Production
- Proliferation Resistance
- Closed Fuel Cycle
- Simplification
- Increased safety

Hydrogen Production

- Hydrogen is ready to play the lead in the next generation of energy production methods.
- Nuclear heat sources (*i.e.*, *a nuclear reactor*) have been proposed to aid in the separation of H from H_20.
- Hydrogen is thermo chemically generated from water decomposed by nuclear heat at high temperature.
- The IS process is named after the initials of each element used (iodine and sulfur).

Hydrogen Production (cont.)



What is nuclear proliferation?

- Misuse of nuclear facilities
- Diversion of nuclear materials

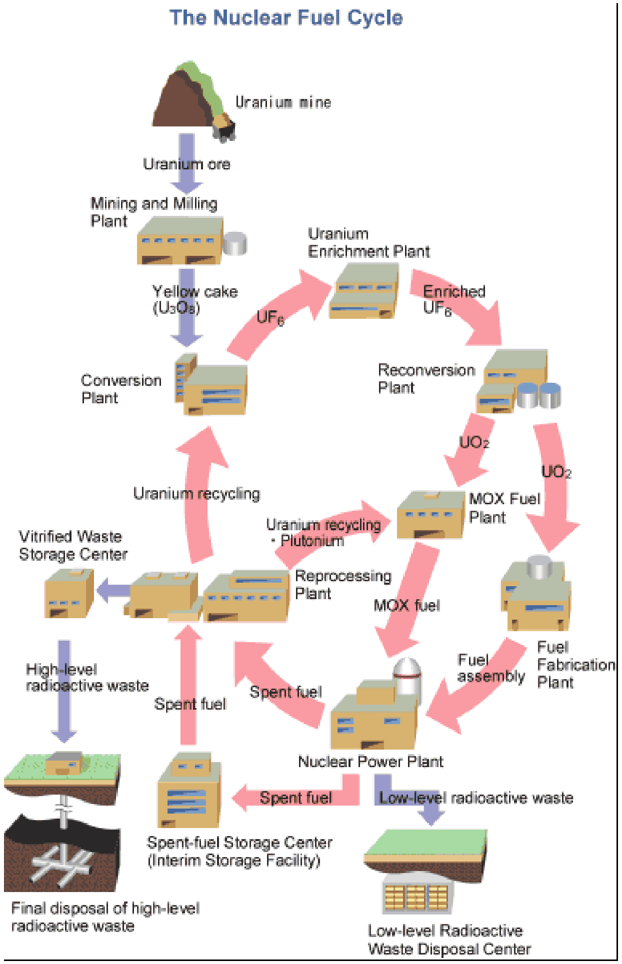
Isotope	Critical Mass (kg)
U-233	15
U-235	50
Pu-238	10
Pu-239	10
Pu-240	40
Pu-241	13
Pu-242	89
Pa-231	162
Np-237	59
Am-241	57
Am-243	155
Cm-245	13
Cm-246	84
Bk-247	10
Cf-251	9

Specific Generation IV Design Advantages

- Long fuel cycle - refueling 15-20 years
- Relative small capacity
- Thorough fuel burn up
- Fuel cycle variability
- Actinide burning
- Ability to burn weapons grade fuel

Closed Fuel Cycle

- A closed fuel cycle is one that allows for reprocessing.
- Benefits include:
  - Reduction of waste stream
  - More efficient use of fuel.
- Negative attributes include:
  - Increased potential for proliferation
  - Additional infrastructure



Simplification

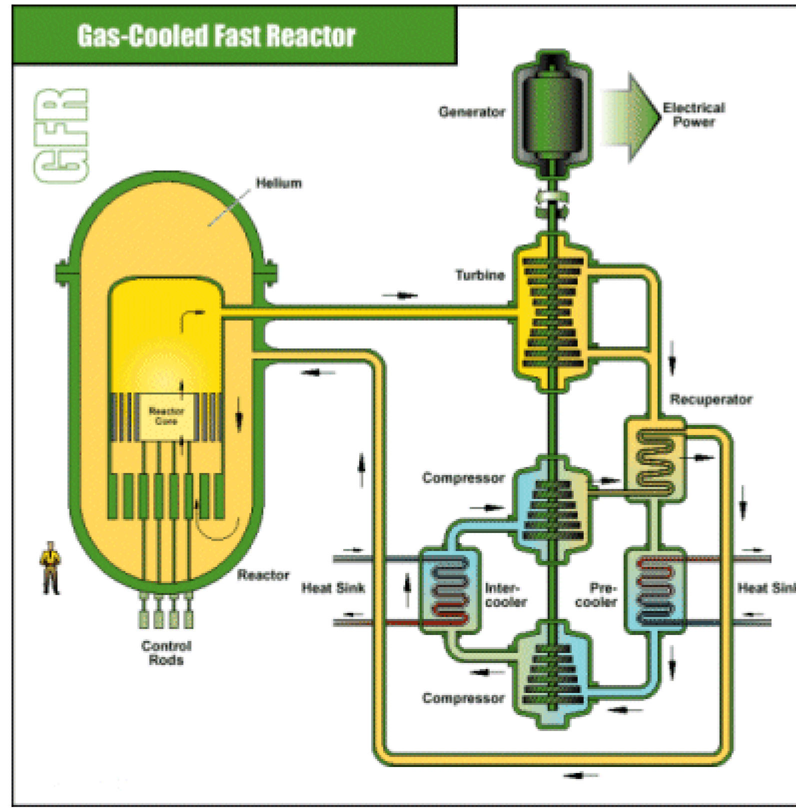
- Efforts are made to simplify the design of Gen IV reactors. This leads to:
  - Reduced capitol costs
  - Reduced construction times
  - Increased safety (less things can fail)

Increased Safety

- Increased safety is always a priority.
- Some examples of increased safety:
  - Natural circulation in systems
  - Reduction of piping
  - Incorporation of pumps within reactor vessel
  - Lower pressures in reactor vessel (liquid metal cooled reactors)

Gas Cooled Fast Reactor (GFR)

- The Gas-Cooled Fast Reactor (GFR) system features:
  - fast-neutron-spectrum
  - helium-cooled reactor (Brayton Cycle)
  - closed fuel cycle (includes reprocessing)

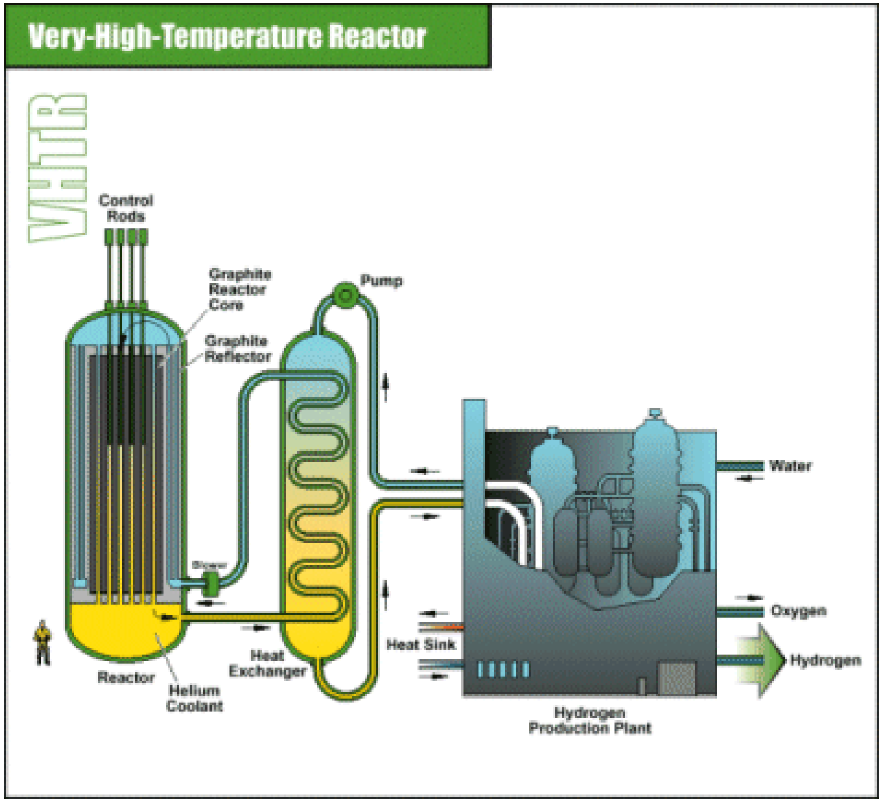


Gas Cooled Fast Reactor (GFR)

- Like thermal-spectrum, helium-cooled reactors, the high outlet temperature of the helium coolant makes it possible to:
  - deliver electricity
  - produce hydrogen
  - process heat with high efficiency.
- The reference reactor is a 288-MWe helium-cooled system operating with an outlet temperature of 850 degrees Celsius using a direct Brayton cycle gas turbine for high thermal efficiency.

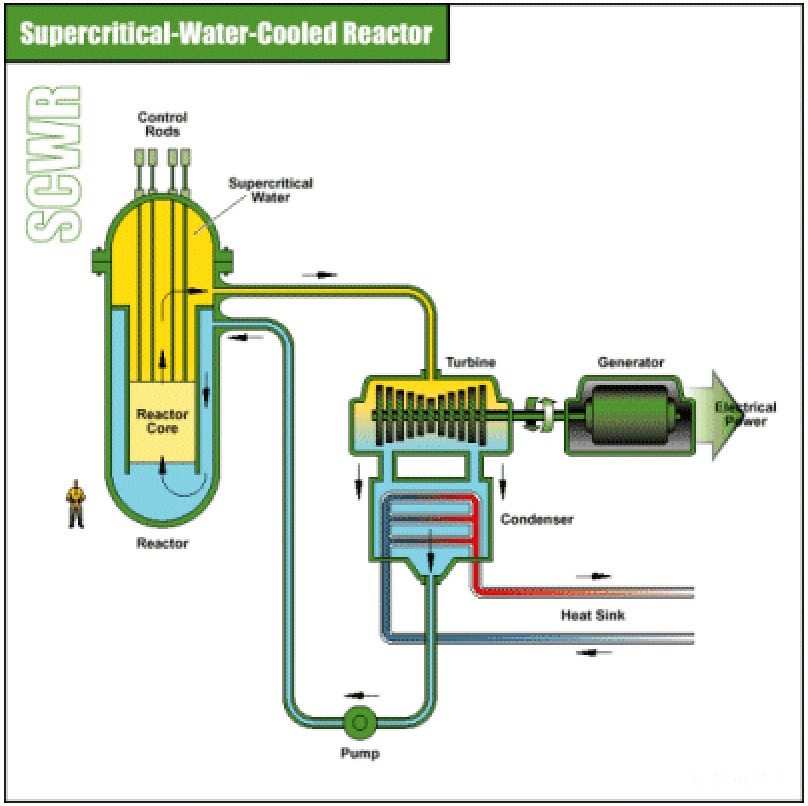
Very High Temperature Reactor (VHTR)

- The Very-High-Temperature Reactor (VHTR) is
  - graphite-moderated (thermal spectrum)
  - helium-cooled reactor
  - once-through uranium fuel cycle (no reprocessing)
  - core outlet temperatures of 1,000 ◦C



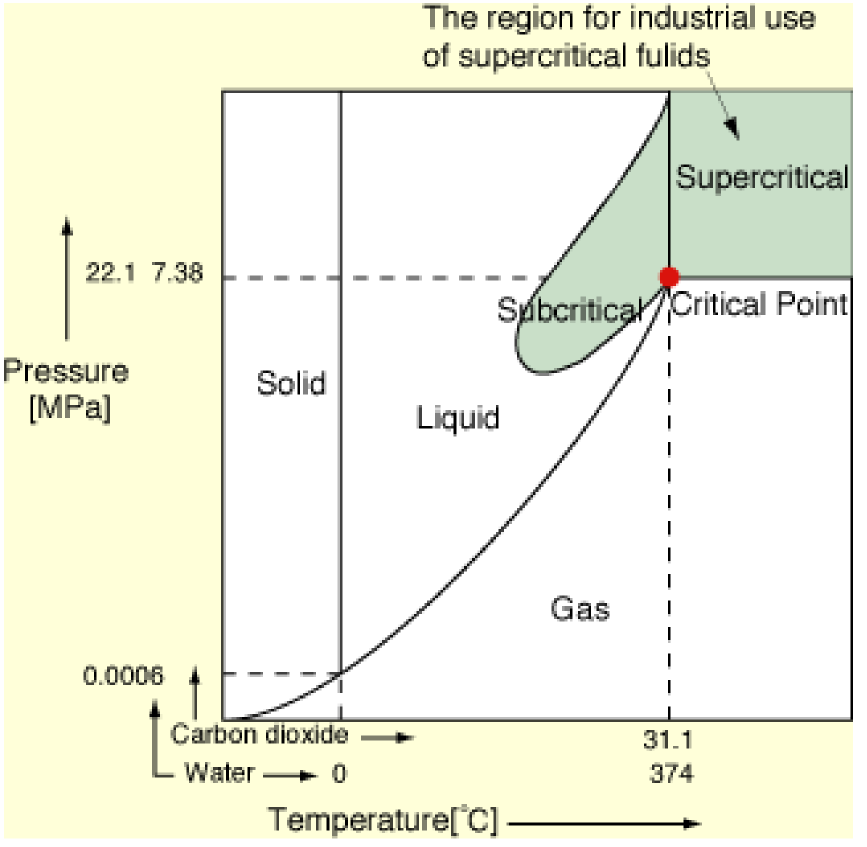
Supercritical Water Cooled Reactor (SCWR)

- The Supercritical-Water-Cooled Reactor (SCWR) system:
  - high-temperature
  - high-pressure water-cooled reactor that operates above the thermodynamic critical point of water (374 degrees Celsius, 22.1 MPa, or 705 degrees Fahrenheit, 3208 psia).



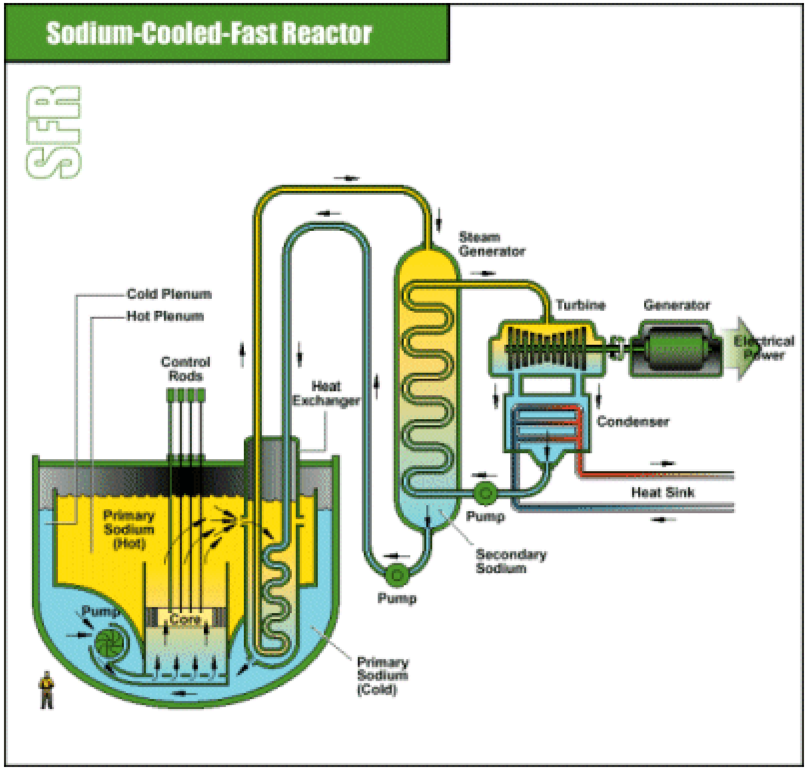
What is a supercritical fluid?

- A supercritical fluid is a material which can be either liquid or gas, used in a state above the critical temperature and critical pressure where gases and liquids can coexist. It shows unique properties that are different from those of either gases or liquids under standard conditions.



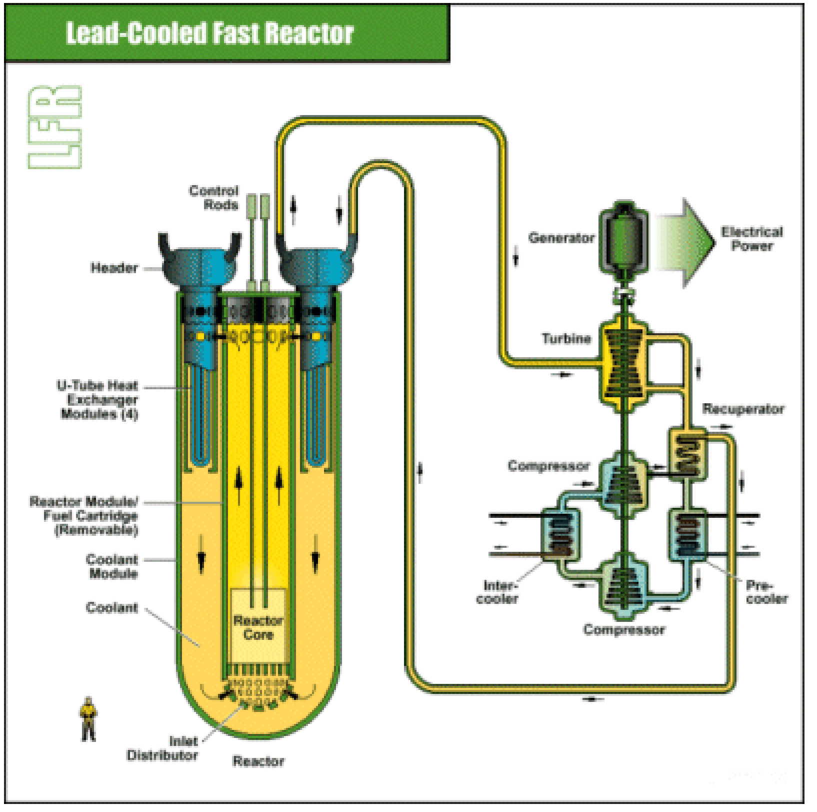
Sodium Cooled Fast Reactor (SFR)

- The Sodium-Cooled Fast Reactor (SFR) system features:
  - fast-spectrum (facilitates breeding)
  - sodium-cooled reactor
  - closed fuel cycle (reprocessing) for efficient management of actinides and conversion of fertile uranium.
  - Rankine Cycle



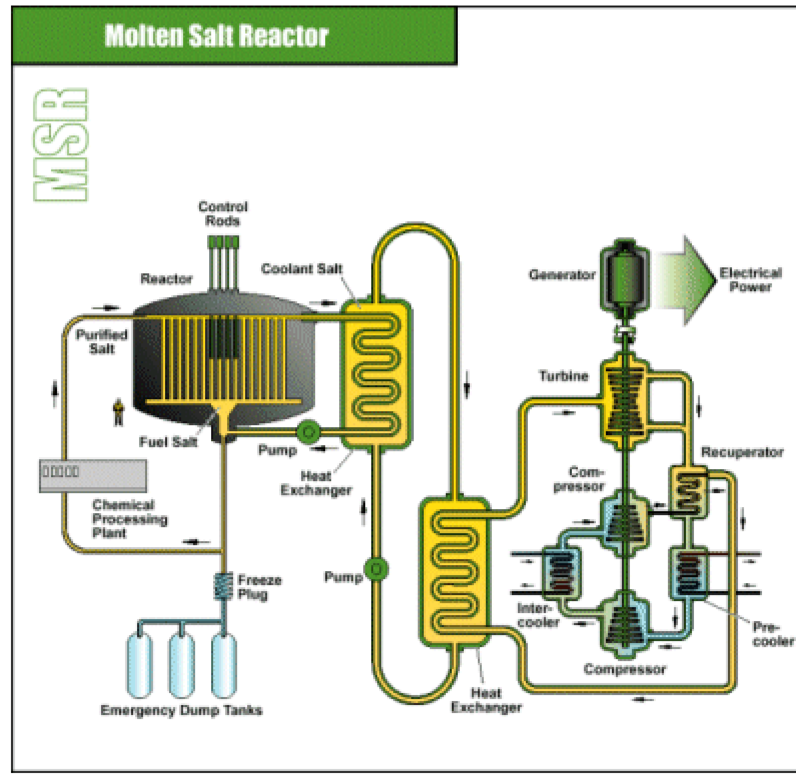
Lead Cooled Fast Reactor (LFR)

- The Lead-Cooled Fast Reactor (LFR) system features:
  - fast-spectrum lead or lead/bismuth eutectic liquid metal-cooled reactor
  - closed fuel cycle (reprocessing) for efficient conversion of fertile uranium and management of actinides.
  - Brayton Cycle
  - higher temperature enables the production of hydrogen by thermochemical processes.
  - very long refueling interval (15 to 20 years) (proliferation resistant)



Molten Salt Reactor (MSR)

- The Molten Salt Reactor (MSR) system produces fission power in a circulating molten salt fuel mixture
  - epithermal-spectrum reactor
  - full actinide recycle fuel cycle.
  - Brayton cycle
- Molten fluoride salts have excellent heat transfer characteristics and a very low vapor pressure, which reduce stresses on the vessel and piping.



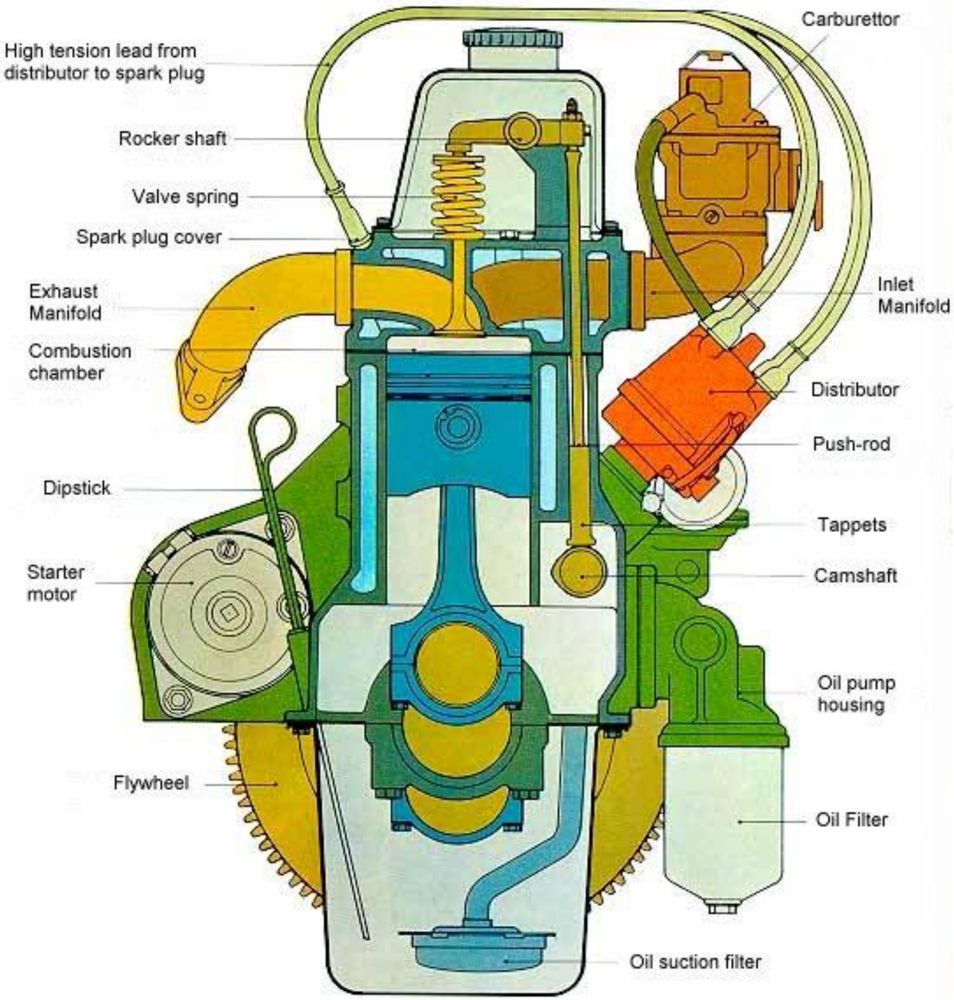
Policy Issues

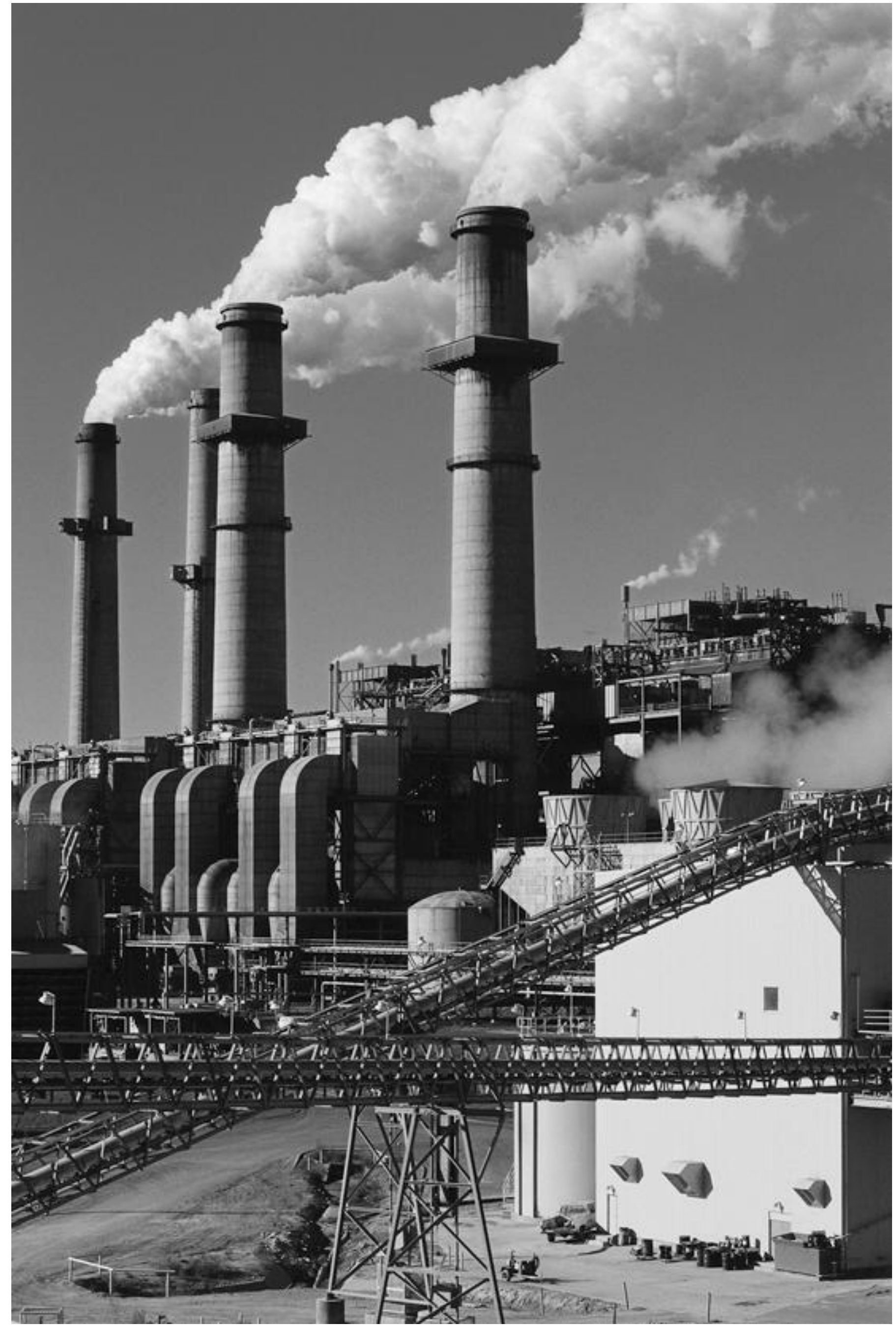
- Many policy issues exist that affect the viability of the future of nuclear power:
  - Licensing
  - Risk insurance
  - Reprocessing of spent nuclear fuel
  - Nuclear waste repository
  - Next generation reactor research
  - Incorporation of hydrogen production into nuclear fuel cycle
  - University nuclear engineering programs

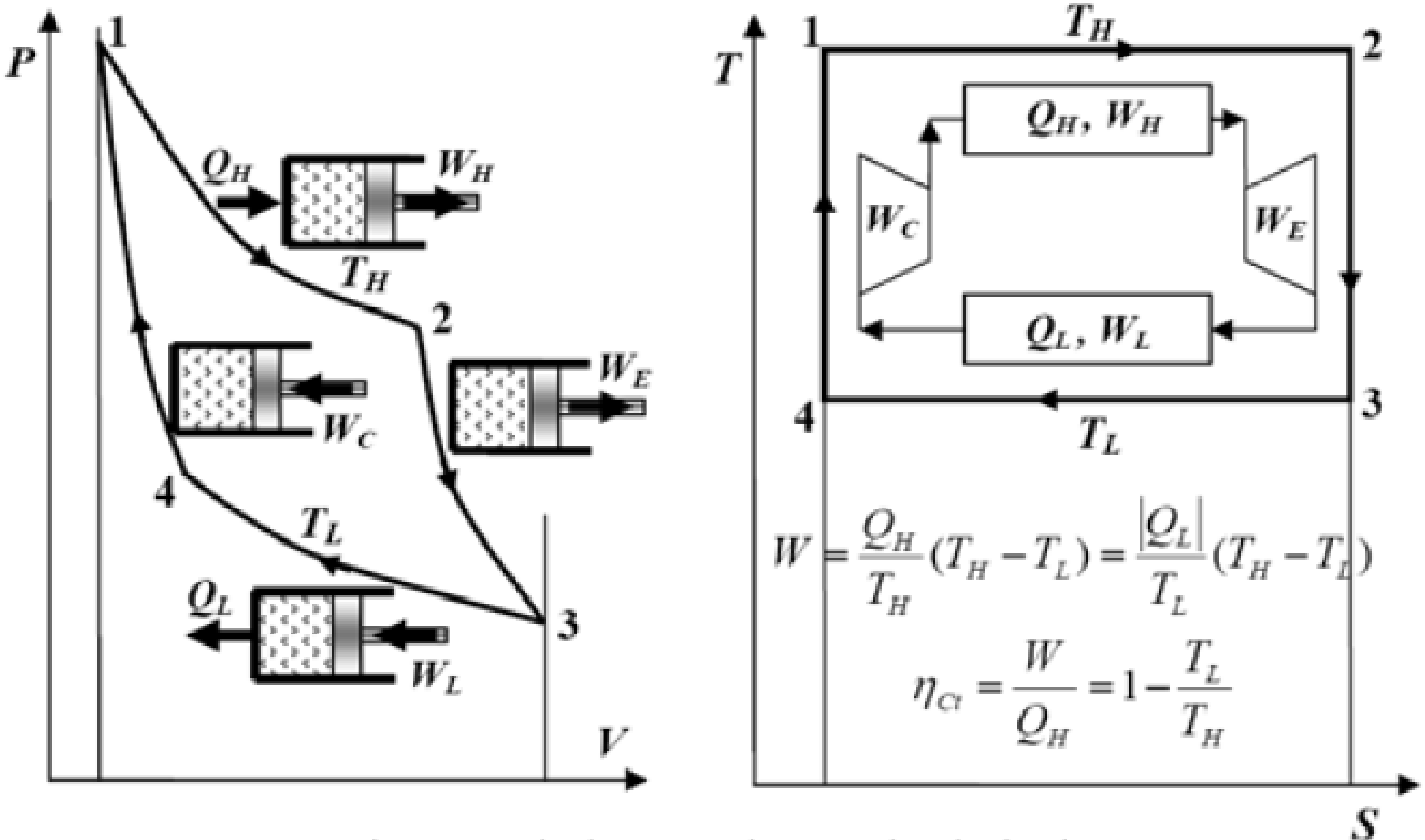
Conclusions

- So, what does the future hold?
  - The demand for electrical power will continue to increase.
  - The world reserves of fossil fuels are limited.
  - Modern nuclear power plant designs are more inherently safe and may be constructed with less capital cost.
  - Fossil fuel-based electricity is projected to account for more than 40% of global greenhouse gas emissions by 2020.
- A 2003 study by MIT predicted that nuclear power growth of three fold will be necessary by 2050.
- U.S. Government has voiced strong support for nuclear power production.

FRONT SECTION OF A 4-CYLINDER INTERNAL COMBUSTION ENGINE







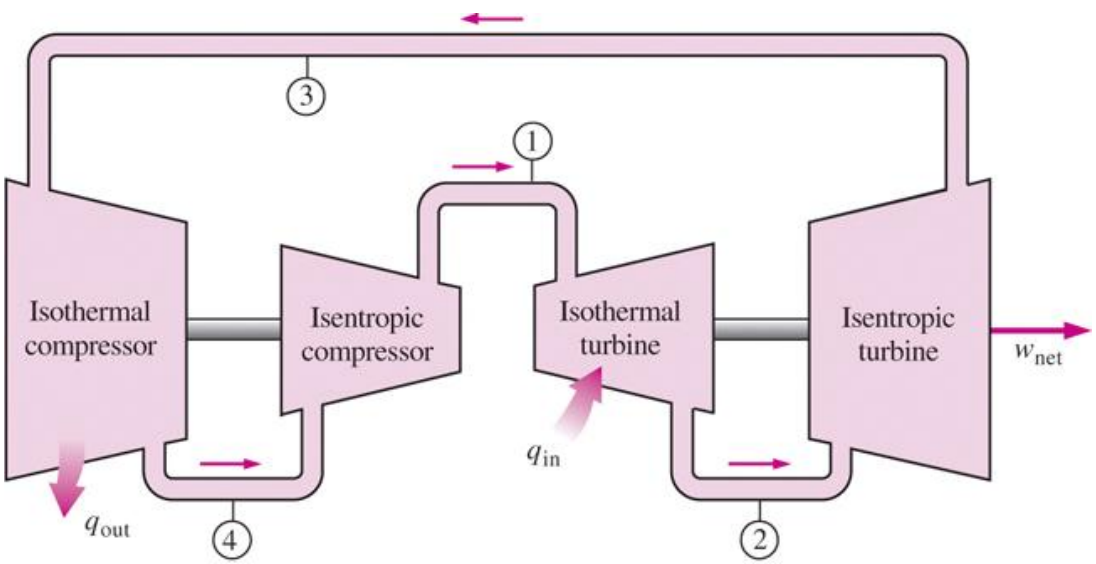
$$\eta_C = \frac{W}{Q_H} = \frac{|W_H + W_E| - |W_L + W_C|}{Q_H} = \frac{|Q_H| - |Q_L|}{Q_H} = 1 - \frac{T_L}{T_H}$$

Fig. 2: Heat-engine ideal *Carnot* cycle: note thermal and mechanical expansions and compressions (the former is needed for net-work out, while the latter is needed to provide reversible heat transfer).

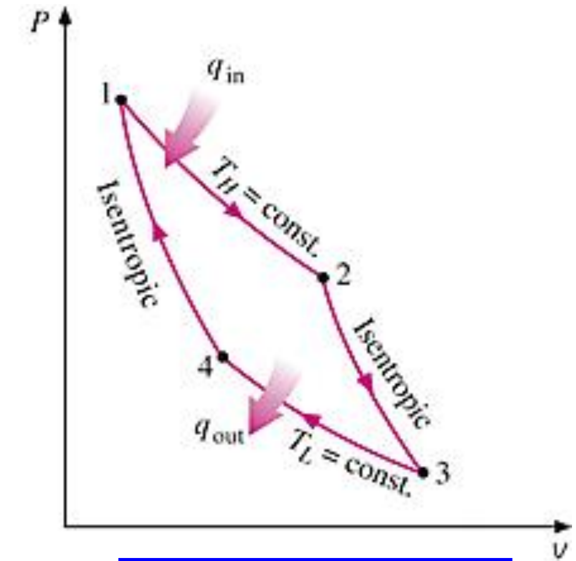
THE CARNOT CYCLE AND ITS VALUE IN ENGINEERING

The Carnot cycle is composed of four totally reversible processes: isothermal heat addition, isentropic expansion, isothermal heat rejection, and isentropic compression.

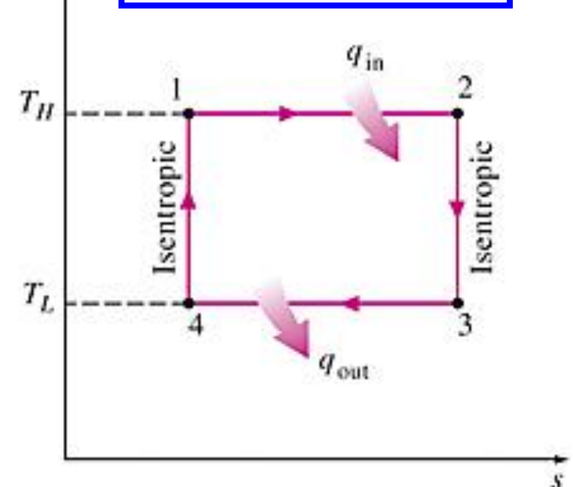
For both ideal and actual cycles: *Thermal efficiency increases with an increase in the average temperature at which heat is supplied to the system or with a decrease in the average temperature at which heat is rejected from the system.*



A steady-flow Carnot engine.



$$\eta_{th,Carnot} = 1 - \frac{T_L}{T_H}$$



P-*v* and *T*-*s* diagrams of a Carnot cycle.

AN OVERVIEW OF RECIPROCATING ENGINES

Compression ratio

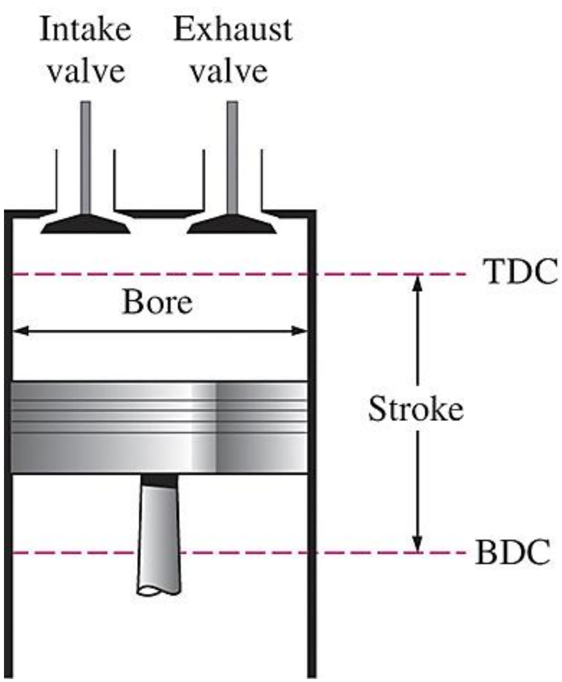
$$r = \frac{V_{\max}}{V_{\min}} = \frac{V_{BDC}}{V_{TDC}}$$

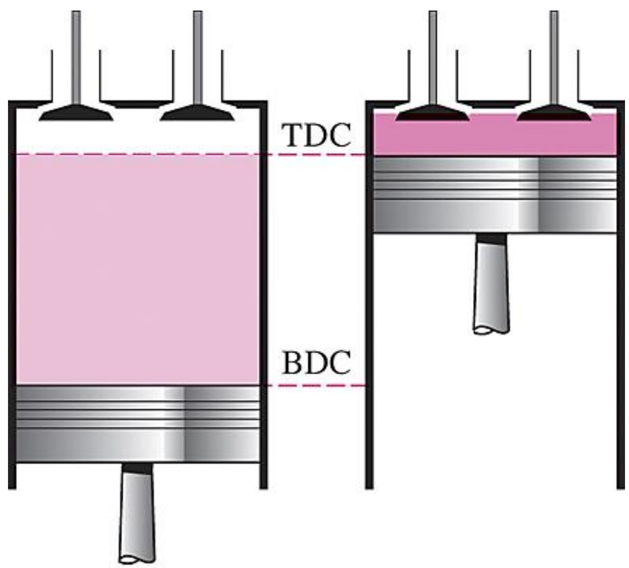
$$W_{net} = MEP \times \text{Piston area} \times \text{Stroke} = MEP \times \text{Displacement volume}$$

Mean effective pressure

$$MEP = \frac{W_{net}}{V_{\max} - V_{\min}} = \frac{w_{net}}{v_{\max} - v_{\min}} \qquad (kPa)$$

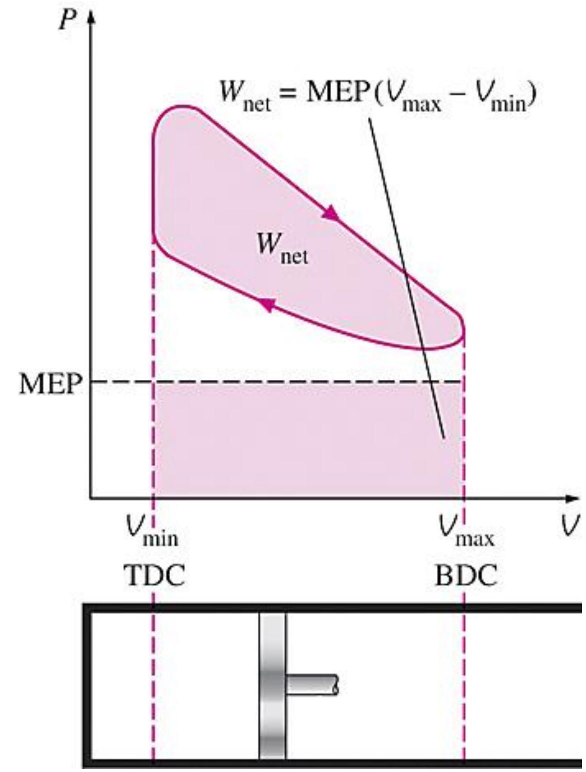
- **Spark-ignition (SI) engines**
- **Compression-ignition (CI) engines**





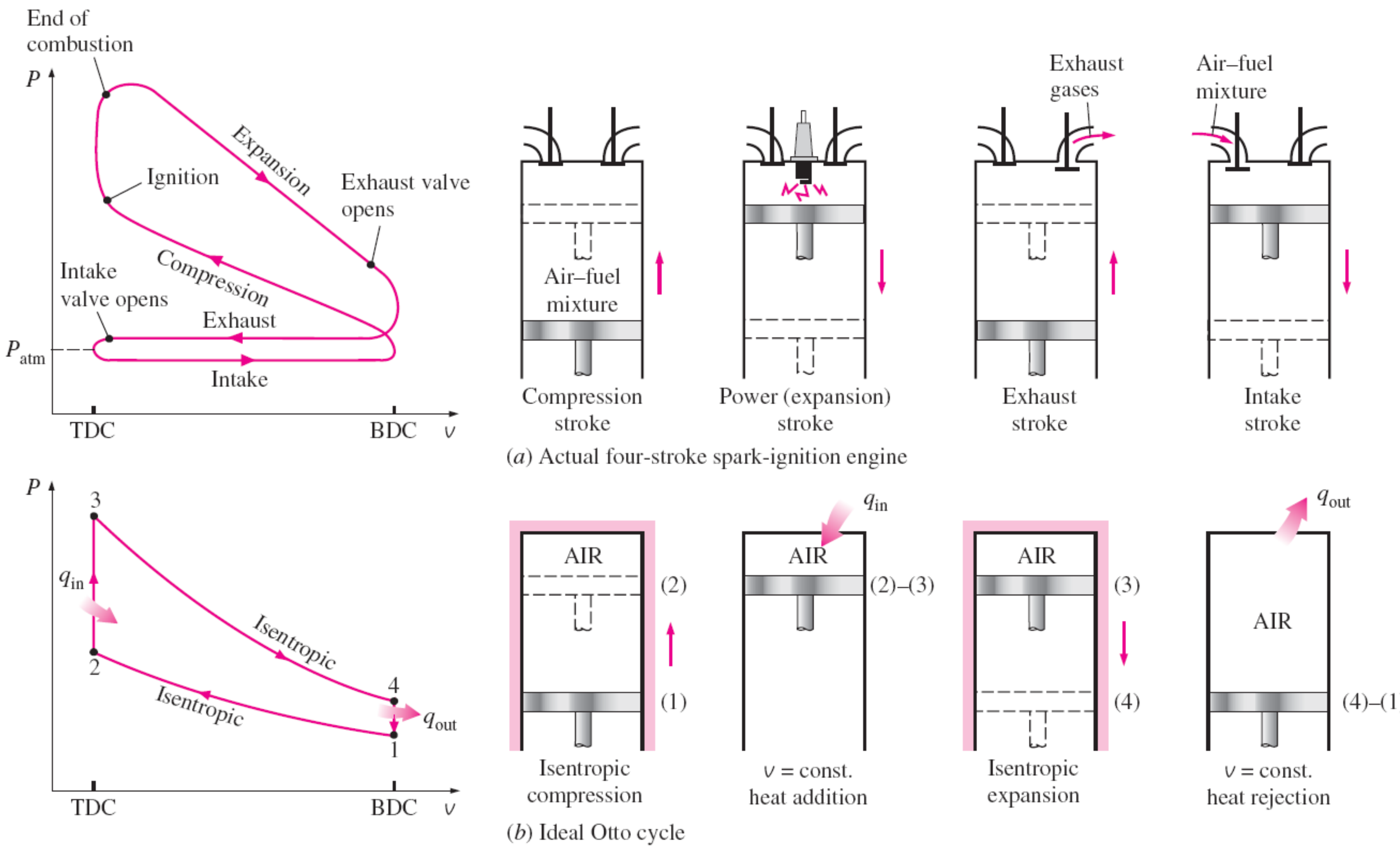
(*a*) Displacement volume

(*b*) Clearance volume



Nomenclature for reciprocating engines.

OTTO CYCLE: THE IDEAL CYCLE FOR SPARK-IGNITION ENGINES

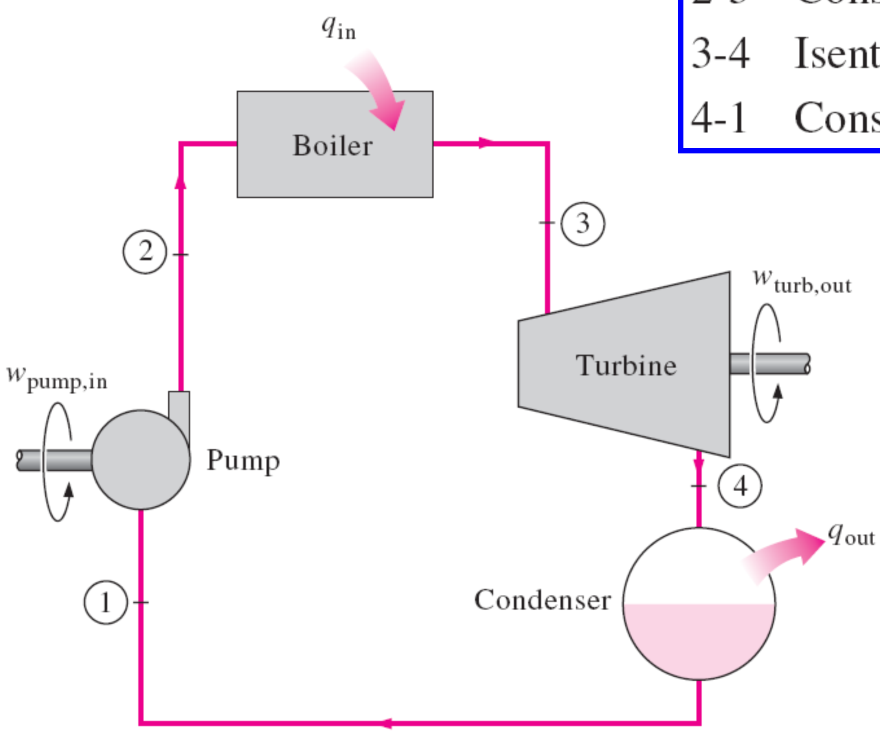


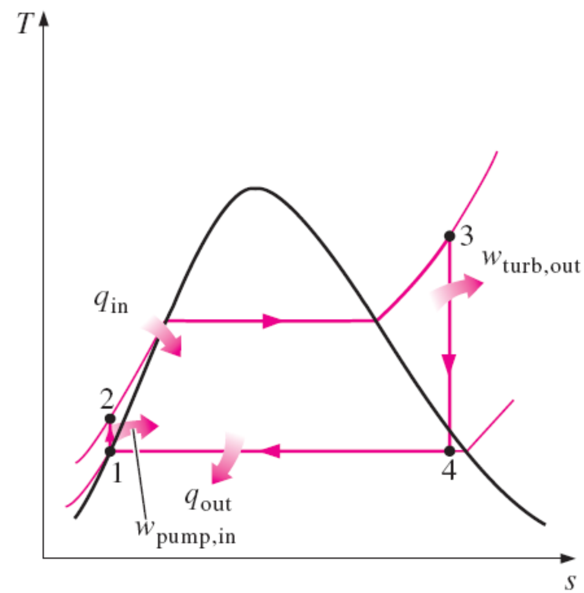
Actual and ideal cycles in spark-ignition engines and their *P*-*v* diagrams.

RANKINE CYCLE: THE IDEAL CYCLE FOR VAPOR POWER CYCLES

Many of the impracticalities associated with the Carnot cycle can be eliminated by superheating the steam in the boiler and condensing it completely in the condenser. The cycle that results is the **Rankine cycle**, which is the ideal cycle for vapor power plants. The ideal Rankine cycle does not involve any internal irreversibilities.

1-2	Isentropic compression in a pump
2-3	Constant pressure heat addition in a boiler
3-4	Isentropic expansion in a turbine
4-1	Constant pressure heat rejection in a condenser

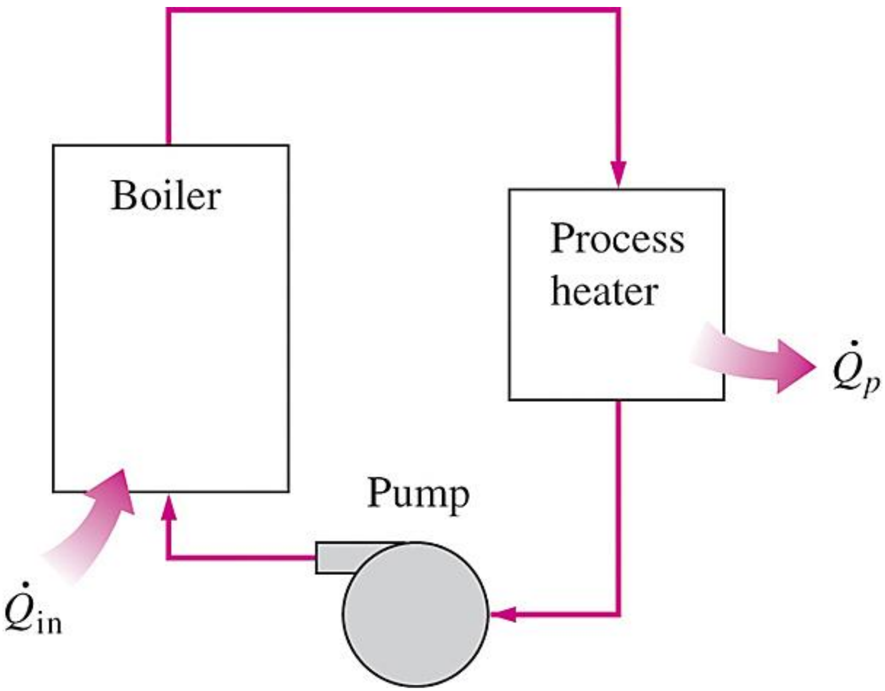




The simple ideal Rankine cycle.

COGENERATION

Many industries require energy input in the form of heat, called ***process heat***. Process heat in these industries is usually supplied by steam at 5 to 7 atm and 150 to 200°C. Energy is usually transferred to the steam by burning coal, oil, natural gas, or another fuel in a furnace.



A simple process-heating plant.

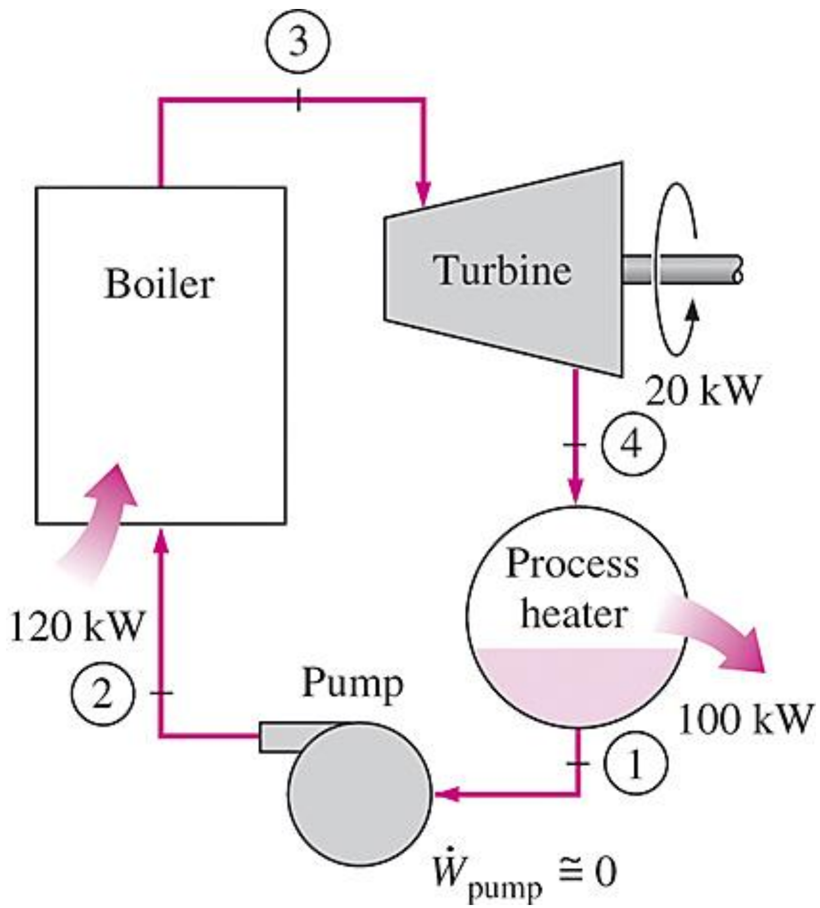
Industries that use large amounts of process heat also consume a large amount of electric power.

It makes sense to use the already-existing work potential to produce power instead of letting it go to waste.

The result is a plant that produces electricity while meeting the process-heat requirements of certain industrial processes (cogeneration plant)

Cogeneration: The production of more than one useful form of energy (such as process heat and electric power) from the same energy source.

Utilization factor $\epsilon_u = \frac{\text{Net work output} + \text{Process heat delivered}}{\text{Total heat input}} = \frac{\dot{W}_{net} + \dot{Q}_p}{\dot{Q}_{in}}$



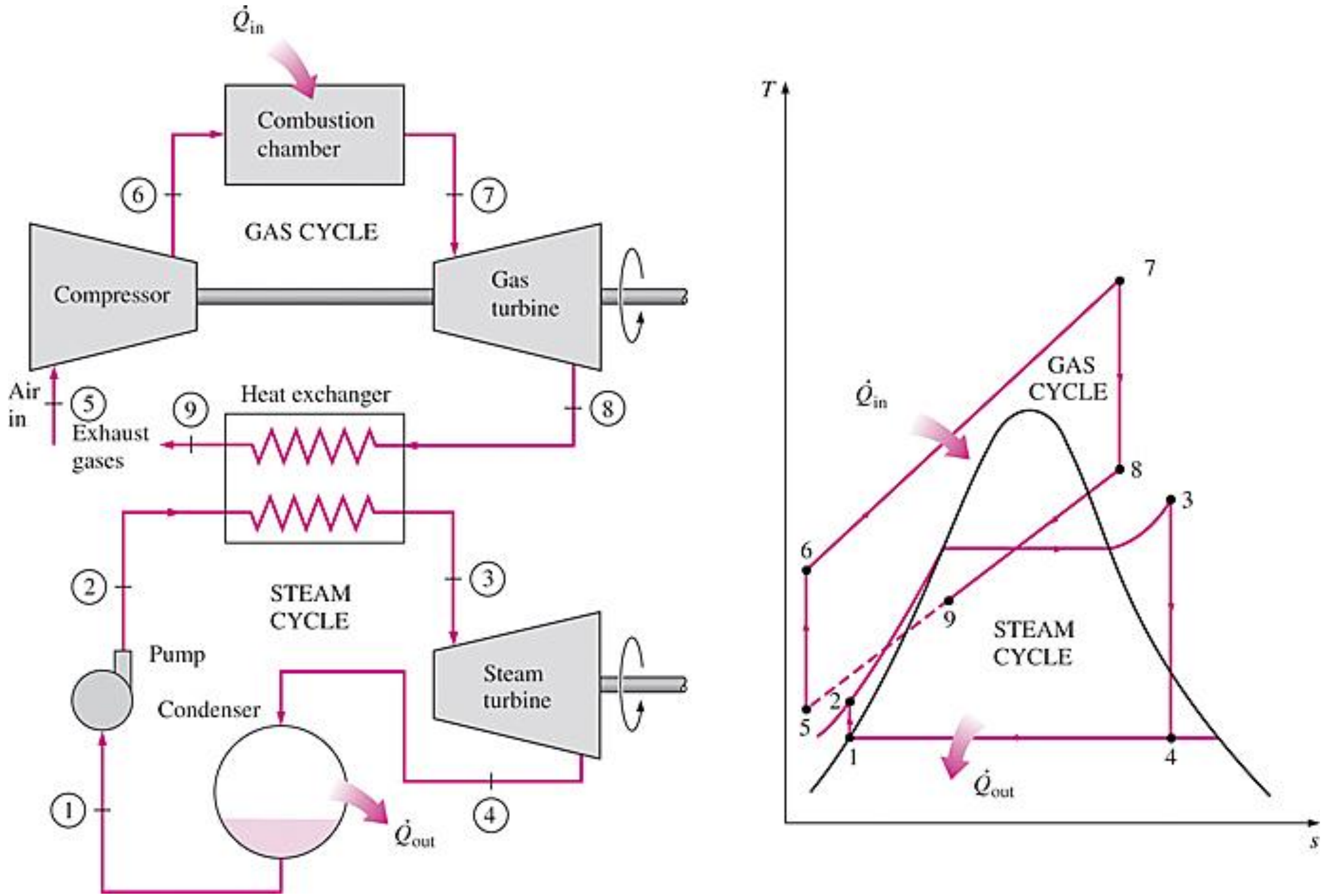
An ideal cogeneration plant.

$$\epsilon_u = 1 - \frac{\dot{Q}_{out}}{\dot{Q}_{in}}$$

- The utilization factor of the ideal steam-turbine cogeneration plant is 100%.
- Actual cogeneration plants have utilization factors as high as 80%.
- Some recent cogeneration plants have even higher utilization factors.

COMBINED GAS–VAPOR POWER CYCLES

- The continued quest for higher thermal efficiencies has resulted in rather innovative modifications to conventional power plants.
- A popular modification involves a gas power cycle topping a vapor power cycle, which is called the **combined gas–vapor cycle**, or just the **combined cycle**.
- The combined cycle of greatest interest is the gas-turbine (Brayton) cycle topping a steam-turbine (Rankine) cycle, which has a higher thermal efficiency than either of the cycles executed individually.
- It makes engineering sense to take advantage of the very desirable characteristics of the gas-turbine cycle at high temperatures *and* to use the high-temperature exhaust gases as the energy source for the bottoming cycle such as a steam power cycle. The result is a combined gas–steam cycle.
- Recent developments in gas-turbine technology have made the combined gas–steam cycle economically very attractive.
- The combined cycle increases the efficiency without increasing the initial cost greatly. Consequently, many new power plants operate on combined cycles, and many more existing steam- or gas-turbine plants are being converted to combined-cycle power plants.
- Thermal efficiencies over 50% are reported.



Combined gas–steam power plant.

UNIT-V

POWER PLANT ECONOMICS AND ENVIRONMENTAL CONSIDERATIONS

The function of a power station is to deliver power at the lowest possible cost per kilo watt hour. This total cost is made up of fixed charges consisting of interest on the capital, taxes, insurance, depreciation and salary of managerial staff, the operating expenses such as cost of fuels, water, oil, labor, repairs and maintenance etc.

Load curve:

Load curve is plot of load in kilowatts versus time usually for a day or a year.

Load duration curve:

Load duration curve is the plot of load in kilowatts versus time duration for which it occurs.

Maximum demand:

Maximum demand is the greatest of all demands which have occurred during a given period of time.

Average load:

Average load is is the average load on the power station in a given period (day/month or year)

Base load:
Base load is the minimum load over a given period of time.

Connected load:
Connected load of a system is the sum of the continuous ratings of the load consuming apparatus connected to the system.

Peak load:
Peak load is the maximum load consumed or produced by a unit or group of units in a stated period of time. It may be the maximum instantaneous load or the maximum average load over a designated interval of time.

Demand factor:
Demand factor is the ratio of maximum demand to the connected load of a consumer.

Diversity factor:

Diversity factor is the ratio of sum of individual maximum demands to the combined maximum demand on power stations

Load factor:

Load factor is the ratio of average load during a specified period to the maximum load occurring during the period.

Load factor = Average Load / Maximum demand

Station load factor:

Station load factor is the ratio of net power generated to the net maximum demand on a power station.

Plant factor:

Plant factor is the ratio of the average load on the plant for the period of time considered, to the aggregate rating of the generating equipment installed in the plant.

Capacity factor:

Capacity factor is the ratio of the average load on the machine for a period of time considered, to the rating of the machine.

Demand factor:

Demand factor is the ratio of maximum demand of system or part of system, to the total connected load of the system, or part of system, under consideration.

CONCLUSION

EVERY PART OF THE PLANT IS PLAYS AN IMPORTANT ROLE FOR THE PLANT. WITHOUT THIS COMPONENTS THE PLANT OR BOILER CANT EVEN RUN AND IF RUNS ALSO THEN THERE IS A100% CHANCE OF A TRIPPING OF PLANT AND BECAUSE OF WHICH VERY HUGE AMOUNT OF LOSSES IN MAN, MONEY AND TIME OCCURES.