# NUCLEAR POWER PLANT

Power Plant Engineering

# Nuclear Power Plants in India

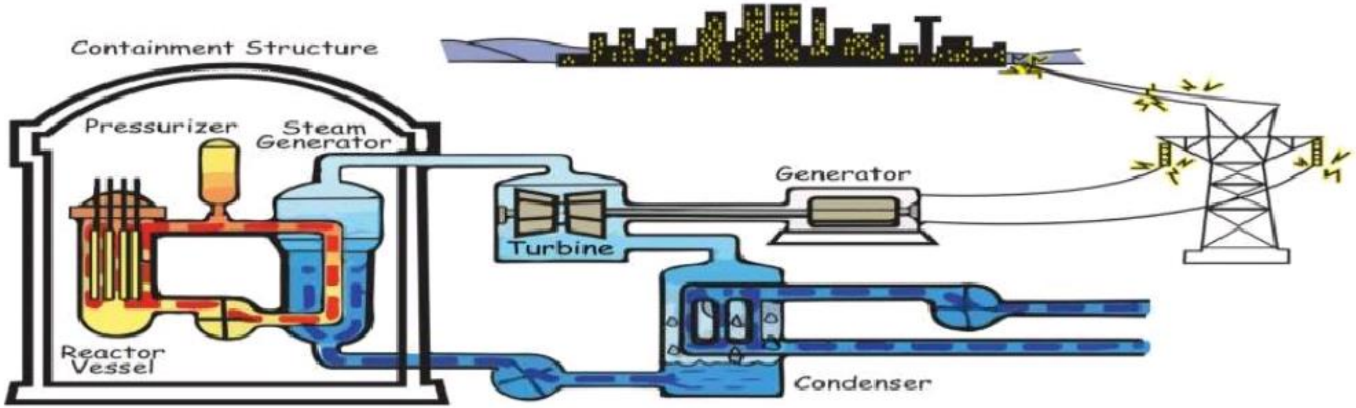
| Name | Type | MW Output | Location | Start Build | Date Critical | Start Power | Planned Stop |
|---|---|---|---|---|---|---|---|
| TAPS-1 | BWR | 160 | Tarapur, Maharashtra | 1964 | 1969 | 1969 | ? |
| TAPS-2 | BWR | 160 | Tarapur, Maharashtra | 1964 | 1969 | 1969 | ? |
| RAPS-1 | PHWR | 100 | Rawatbhata, Rajasthan | 1964 | 1972 | 1973 | ? |
| RAPS-2 | PHWR | 200 | Rawatbhata, Rajasthan | 1968 | 1980 | 1981 | 2011 |
| MAPS-1 | PHWR | 220 | Kalpakkam, Tamil Nadu | 1970 | 1983 | 1984 | 2014 |
| MAPS-2 | PHWR | 220 | Kalpakkam, Tamil Nadu | 1971 | 1985 | 1986 | 2016 |
| NAPS-1 | PHWR | 220 | Narora, Uttar Pradesh | 1976 | 1989 | 1991 | 2021 |
| NAPS-2 | PHWR | 220 | Narora, Uttar Pradesh | 1976 | 1991 | 1992 | 2022 |
| KAPS-1 | PHWR | 220 | Kakrapara, Gujarat | 1983 | 1992 | 1993 | 2023 |
| KAPS-2 | PHWR | 220 | Kakrapara, Gujarat | 1983 | 1995 | 1995 | 2025 |
| Kaiga-1 | PHWR | 220 | Karwar, Karnataka | 1988 | 2000 | 2000 | 2030 |
| Kaiga-2 | PHWR | 220 | Karwar, Karnataka | 1988 | 1999 | 2000 | 2030 |
| RAPS-3 | PHWR | 220 | Kota, Rajasthan | 1988 | 1999 | 2000 | 2030 |
| RAPS-4 | PHWR | 220 | Kota, Rajasthan | 1988 | 2000 | 2000 | 2030 |
| TAPS-4 | PHWR | 540 | Tarapur, Maharashtra | 2000 | 2005 | 2005 | 2035 |

## OPERATING PRINCIPLE OF NUCLEAR POWER PLANT

The working of a nuclear power plant is exactly similar to that of steam power plant, except steam is generated in nuclear reactor instead of boiler. The heat energy is produced by nuclear fission

Fission of atom takes place. This process liberates large amount of heat. This heat is taken up by the coolant circulating through the rector core.

The Pressurized-Water Reactor (PWR)



# GENERAL ARRANGEMENT OF NUCLEAR POWER PLANT

**1. Nuclear reactor:**

Reactor is the heart of the nuclear plant. In nuclear reactor, nuclear fission of radioactive material takes place. This liberates large amount of heat energy. This heat is taken up by the coolant circulating through the reactor core. After absorbing the heat, the coolant becomes hot.

**2. Heat exchanger or Steam generator:**

The hot coolant coming from nuclear reactor flows through the tubes of heat exchanger (or steam generator). In the heat exchanger, hot coolant gives up the heat to feed water, so that it can be converted in to steam.

**3. Steam turbine:**

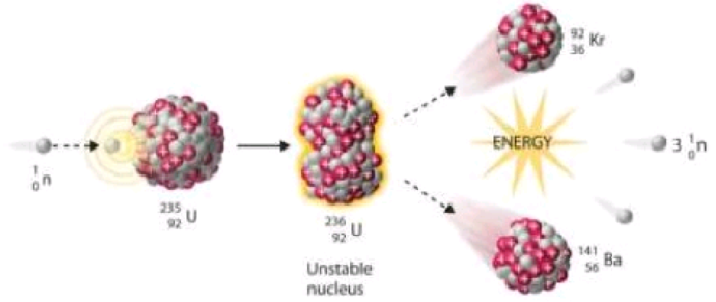
The steam produced in the heat exchanger is sent to steam turbine. The steam undergoes expansion in steam turbine and produces useful work in the steam turbine.

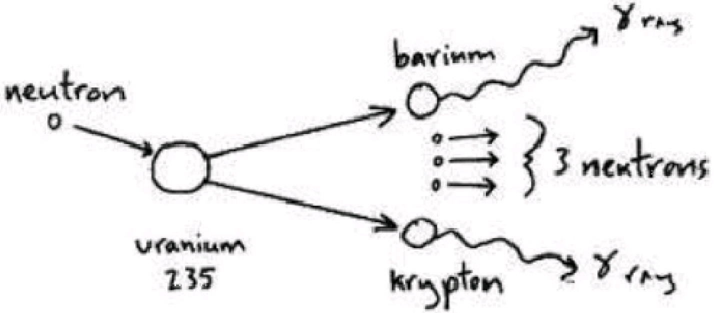
| Comparative point | Steam Power Plant | Nuclear Power plant |
|---|---|---|
| Site | Located near load center. | Location depends upon availability Site of water & away from load center and populated area. |
| Capital cost | Low. | Very high |
| Operating Cost | More | Less |
| Maintenance cost | Moderate | Higher |
| Supervisory staff required | More | Less |
| Space required | More | Less |
| Fuel consumption | Huge | Less |
| Reliability of plant operation | Low | High |
| Qty water required | Huge | Comparatively Less |

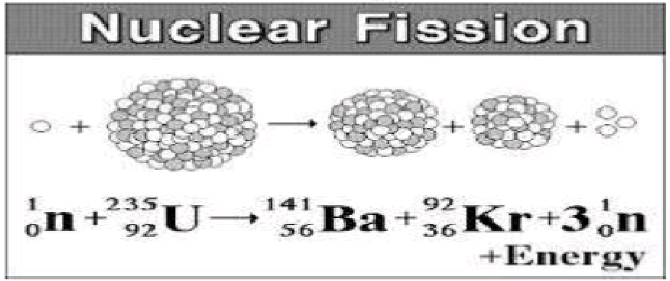
# Nuclear Fission process:-

Fission is defined as, "the process of splitting of a heavy nucleus into lighter nuclei with the release of large amount of energy."

Each way of splitting U nucleus ejects different number of neutrons 1, 2 or 3. On an average neutrons are ejected per neutron absorbed. Out of 25 neutrons, nearly 0.2 to 0.3 neutrons are lost due to escape at the surface and remaining 2.2 eutrons are allowed to continue chain reaction. The reaction rate will increase exponentially and large amount of energy is released.



# Nuclear Chain Reaction

Chain reaction is defined as, "the process, in which, the number of neutrons keeps on multiplying rapidly during fission, till whole of the fissionable material is disintegrated."

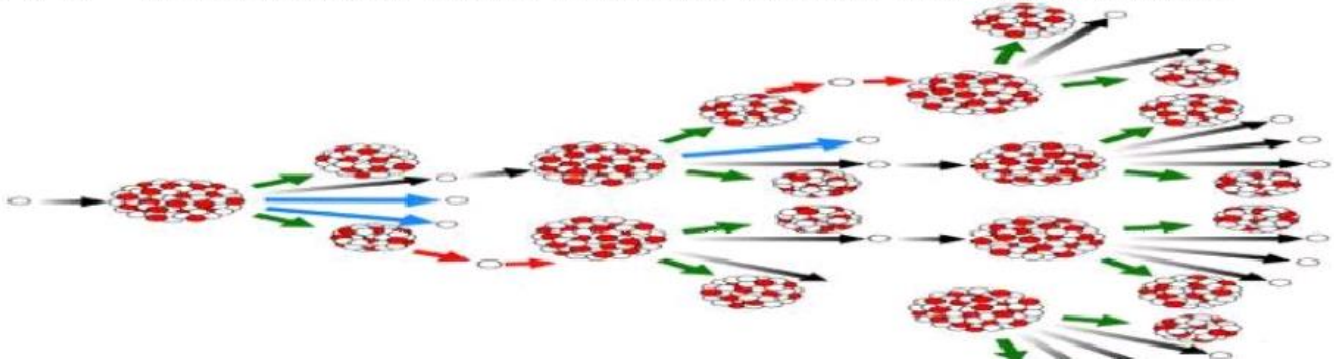
**Multiplication or Reproduction factor, K =**

Number of neutrons in any particular generation / Number of neutrons in any preceding generation .

If $K > 1$, then fission process becomes uncontrolled.

ii) if $k < 1$, the fission process stops,

(iii) If $K = 1$, the fission chain reaction will be self-sustainable

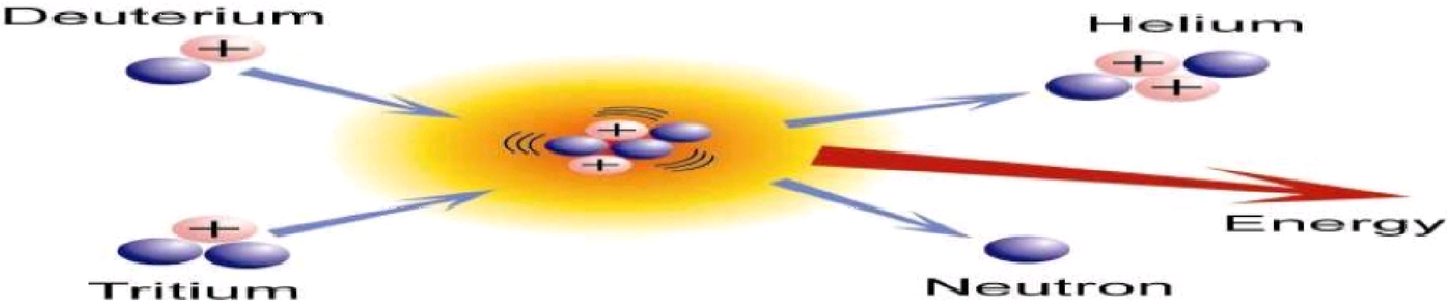


# Nuclear Fusion

Fusion is the defined as, "the process of combining or fusing two lighter nuclei into a stable and heavier nucleus".

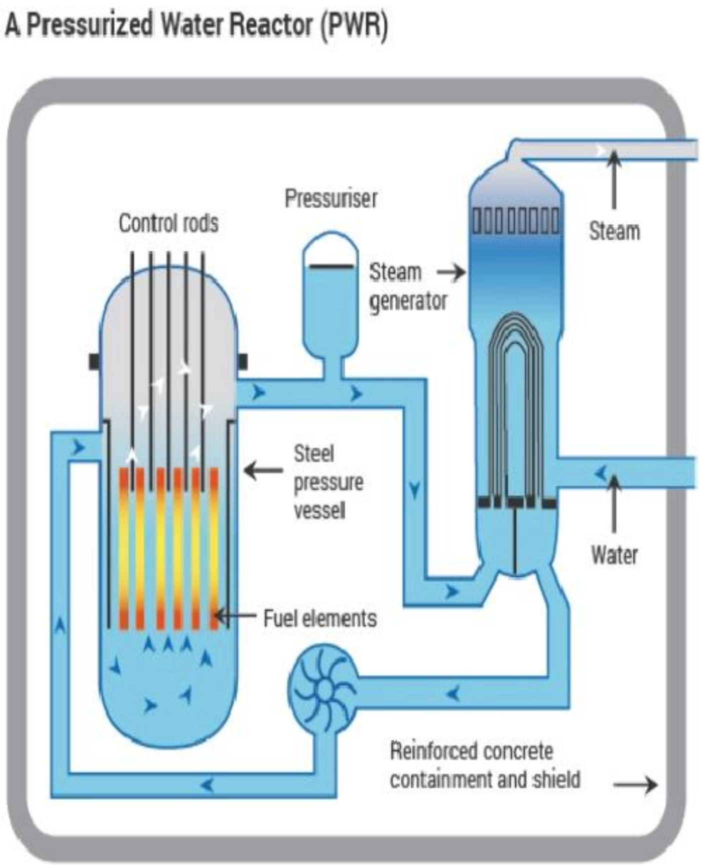
To generate energy in fusion process, the two lighter nuclei (say Tritium and Deuterium) must be heated up to extremely high temperatures (around 30 million degree centigrade) for fusion to take place This not practically feasible.

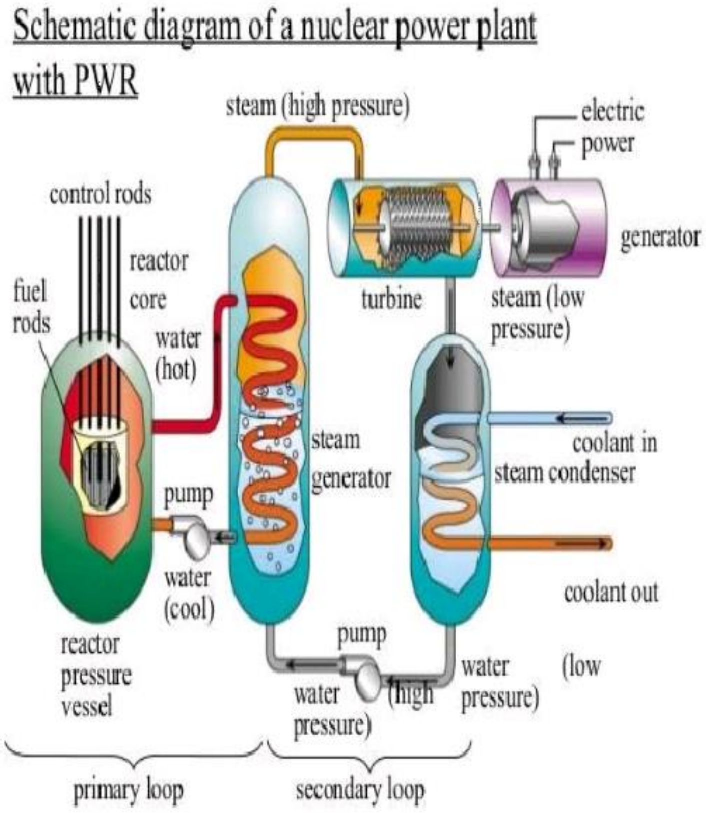
*Due to lesser radioactivity, fusion reaction is less hazardous to common health. But, it is extremely difficult to construct controlled fusion reactors.*



| FISSION | FUSION |
|---|---|
| When heavy unstable nucleus is bombarded with neuron, the nucleus split into fragments of equal mass and heat energy is released. | Some light elements fuse together with the release of energy. |
| About (1/1000) of the mass is converted into energy. | It is possible to have (1/4000) of mass converted into energy. |
| The process is possible at room temperature. | The process is possible only at very high temperature (around 30 million degree centigrade). |
| Because of higher radioactive material health hazards are high in case of accidents. | Because of lesser radioactive material, hazards are much less. |
| It is possible to construct self-sustained fission reactors and have positive energy release. | It is extremely difficult to construct controlled fusion reactors. |

# COMPONENTS OF NUCLEAR REACTOR



# COMPONENTS OF NUCLEAR REACTOR

**1. Reactor core:** The reactor core is a part of nuclear power plant, where fission chain reaction is made to occur and where fission energy is liberated in the form of heat for operating power plant.

The core of the reactor consists of an assembly of fuel elements, control rods, coolant and moderator.

**2. fuel element:** Natural Uranium (containing 0.7% $U^{235}$ ) or enrich 2.5 % $U^{235}$).

**3. Moderator:** To reduce the energy of neutrons evolved during fission in order to mam the fission chain reaction. Commonly used moderators: Ordinary water, Heavy water, Graphite and Beryllium. By the slowing down of high-energy neutrons, the possibility of escape of neutrons is reduced and me slowing down of high-energy neutrons increase

**4. Reflector:** The neutrons, which may escape from the surface of the core without taking part in fission, can be reflected back into the core to take part in the fission reaction with the help of a reflector. Commonly used moderators also work as reflectors.

**5. Coolant:** To transfer the heat generated in reactor core and use it for steam generation. Commonly used coolants: Ordinary water, heavy water, and $CO_2$ used in power reactors.

**6. Control rods:** i) To allow only one neutron evolved in each fission reaction to take part in further fission reaction to just maintain the chain. (ii) To vary the output according to load and shutdown the reactor under emergency conditions. When shutting-down of the reactor is required, the control rod absorbs more number of neutrons than emitted and thus, fission reaction ends.

- Commonly used materials for control rods: Cadmium, Boron etc.

**7. Shielding:** To protect the walls of the reactor vessel from radiation damage & To protect operating personnel from exposure to radiation.

# CLASSIFICATION OF NUCLEAR REACTORS

**1. On the basis of Neutron Energy**

I) Fast reactors (II) Slow or thermal reactors III) Intermediate reactor

**2. On the basis of Type of Fuel Used**

i)Natural Uranium 0.7% $U^{235}$ , ii) Enriched Uranium 2.5% to 10% $U^{235}$

**3. On the basis of Type of Coolant Used**

i) Water cooled reactors , ii) Heavy water-cooled reactor

iii) Liquid metal (sodium) cooled reactors, iv) Gas cooled reactors.

**4. On the basis of Type of Moderators Used:**

i) Water (H2O), ii) Heavy water reactors (D20),

iii) Graphite reactors, iv) Beryllium reactors.

**5. On the basis of Type of fuel - Moderator Assembly**

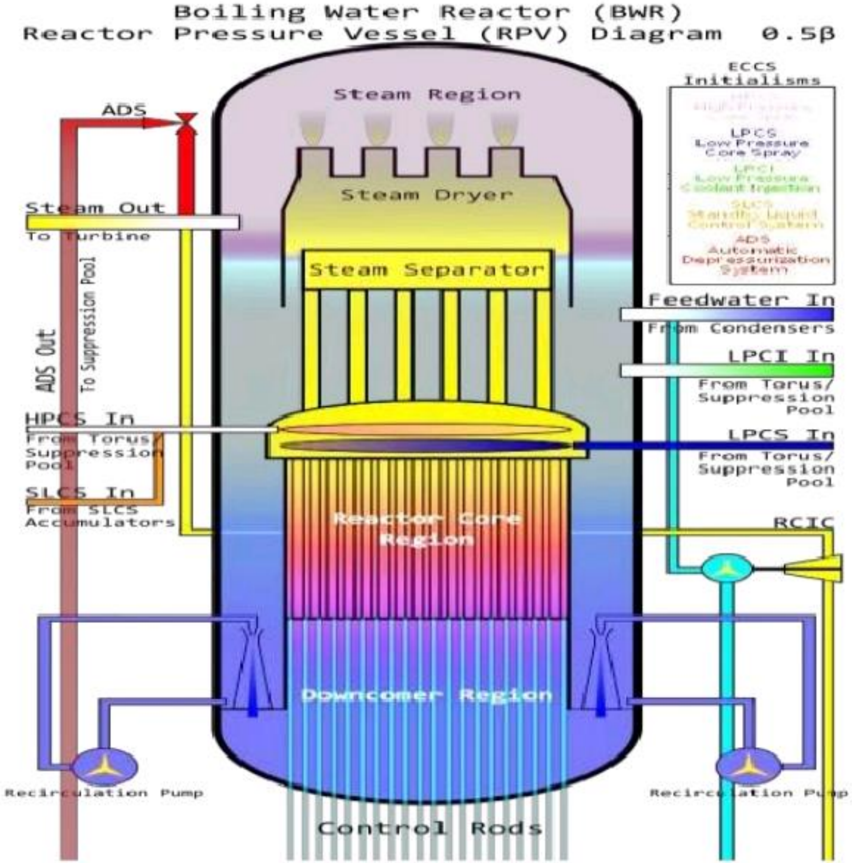
i) Homogenous reactors, ii) Heterogeneous Reactor.

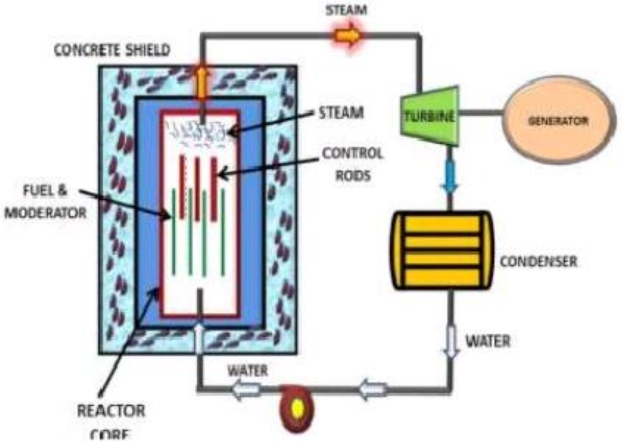
**6. On the basis of Type of Application or Principal Product:**

i) Power reactors: to produce heat, ii) Breeder reactors :to produce fissionable materials, iii) Production reactor: To produce isotopes.

*iv) Research reactors: to produce neutrons*

# Boiler Water Reactor (BWR)




**Coolant used:** Ordinary water

**Moderator used :** Ordinary water

**Fuel used:** Enriched Uranium

e.g. Tarapur power station.

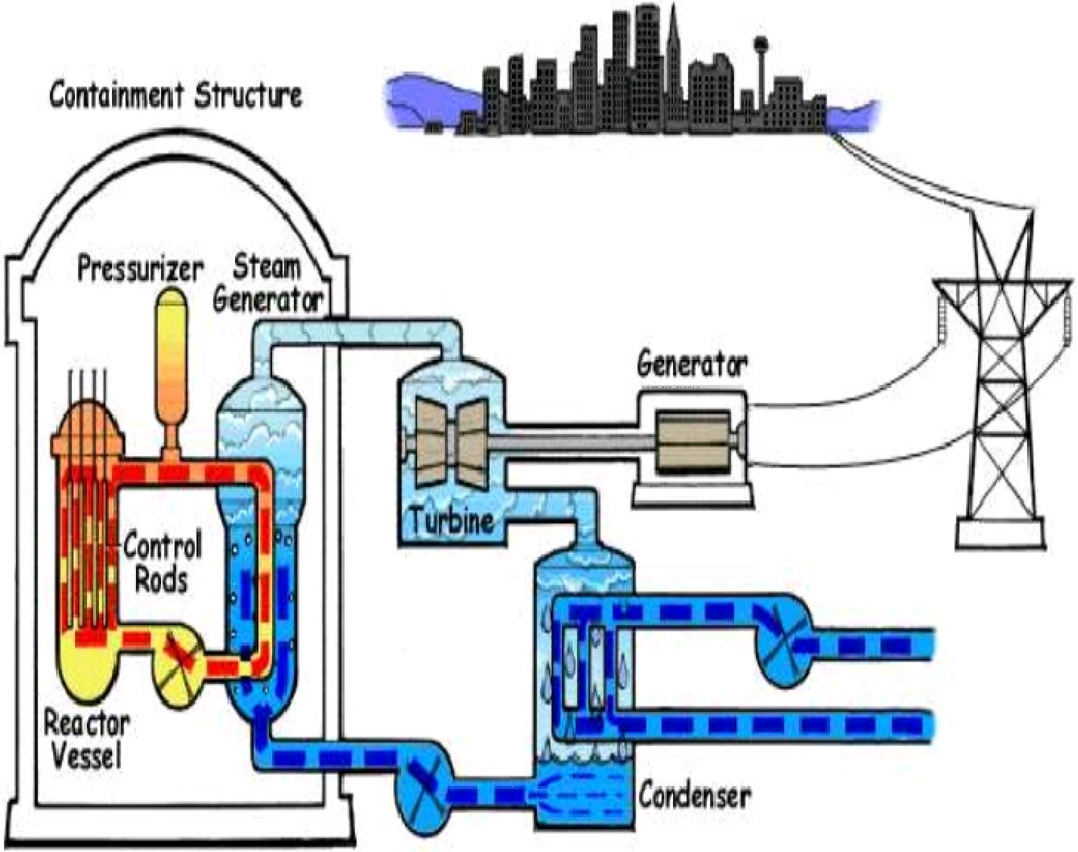
## Advantages of BWR

1. As heat exchanger circuit is eliminated and the steam is directly generated in the reactor, the thermal efficiency of this plant is higher than PWR.
2. The capital cost is lower as the reactor vessel is designed to take low stresses, as the pressure in the vessel is lower than PWR.
3. The number of equipment's required is less.
4. There is use of low-pressure vessels for the reactor, which further reduces capital cost.

## Disadvantages of BWR

1. It is not possible to meet the sudden increase in demand.
2. Shielding of turbine and other components is necessary, because radioactive steam enters into the turbine.
3. The power density is 50% of PWR.
4. The possibility of "burn out" of fuel is more than PWR.

# PRESSURIZED WATER REACTOR (PWR)




**Coolant used:**
Ordinary water
**Moderator used :**
Ordinary water
**Fuel used:**
Enriched Uranium

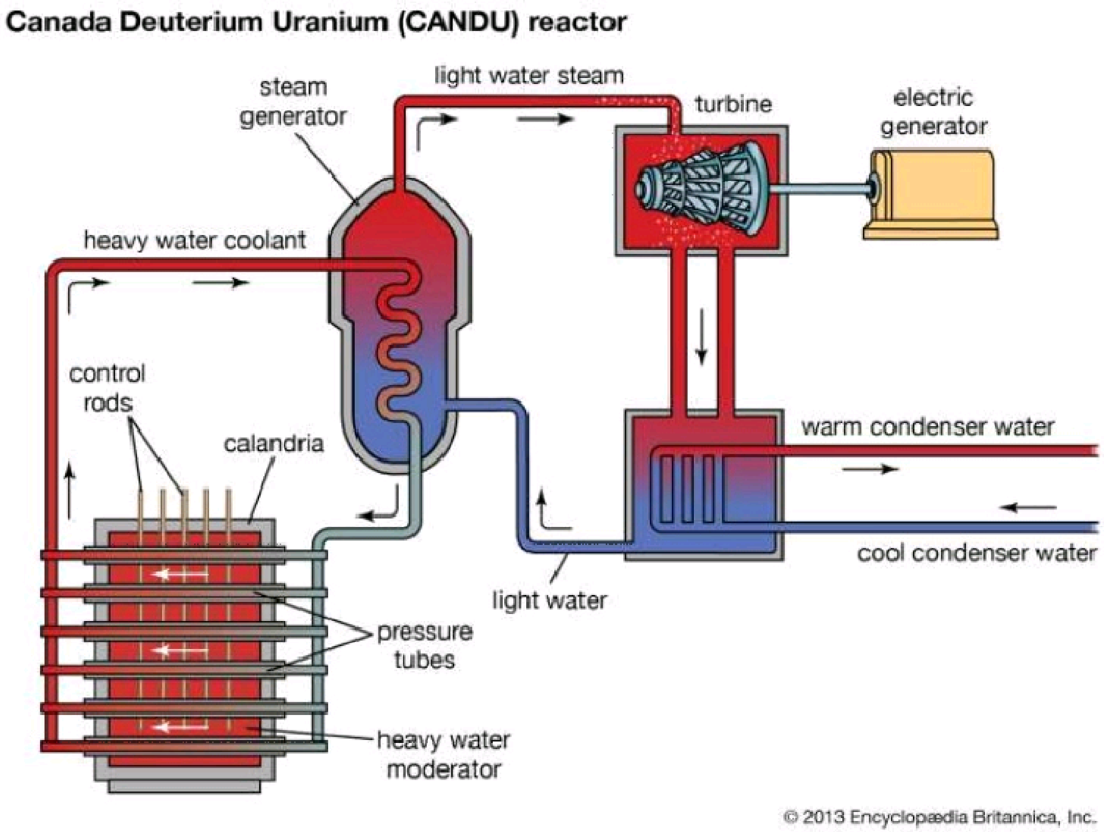
## Advantages of PWR

1. The ordinary water is used as a coolant and moderator, which is considerably cheap and easily available,
2. The reactor is compact and its power density is 65 kW/litre.
3. This reactor reduces fuel cost by extracting more energy per unit weight of fuel
4. Less number of control rods are required.
5. Steam is not contaminated by radioactivity.
6. Fission products remain contained in the reactor, i.e. they are not circulated

## Disadvantages of PWR

1 The capital cost of reactor is high, as it requires strong pressure vessel
2. The running cost of reactor is high, as it uses enriched Uranium.
3. Thermodynamic efficiency of the cycle is low.
4. The erosion and corrosion problems are more severe.

# Heavy Water Cooled Or Moderated Or CANDU Type Reactor Or Canadian Deutorium Uranium Reactor




**Coolant used:** Heavy water

**Moderator used :** Heavy water

**Fuel used:** Natural Uranium

## Advantages of CANDU Reactor

1. Natural uranium can be used as fuel.

2. Only fuel tubes are designed to withstand high pressure and reactor vessel can be made of light material.

3. Easy to control. 4. Fuel consumption is low.

5. Period required for construction is shorter than for PWR and BWR.

6. The moderator can be kept at low temperature, which increases the effectiveness in slowing down neutrons.

## Disadvantages of CANDU Reactor

1. The cost of heavy water is very high.

2. Leakage of heavy water is one of the major problems in construction of reactor.

3. Reactor requires high standards in the areas of design, manufacturing and maintenance.

4. The power density is low. Therefore, the reactor size is considerably large as compared to DWP and BWR.

## SAFETY PRECAUTIONS/MEASURES FOR NUCLEAR POWER PLANT

i) Plant should be constructed away from human habitation. An exclusion zone of 106 km radius around the plant should be provided, where no public habits.

ii) The materials to be used for the construction of a nuclear power plant is standards.

iii) Waste water from plant should be purified.

iv) The plant must be provided with such a safety system which is shutdown the plant as and when necessity arises.

V) There must be periodic checks to ensure that, radioactivity does not exceed the permissible.

vi) While disposing off the waste from the nuclear plants, there is no pollution of water of river or sea.

# NUCLEAR WASTE DISPOSAL

## 1. Solid waste:

It consists of discarded control rods, fuel cans, scrap material etc. Out of these, the combustible matter is burnt and the resulting gases are disposed to atmosphere, after dilution.

The remaining material is mixed with concrete in the form of shielded vaults and buried deep in sea or ground.

## 2. Liquid waste:

Liquid waste coming from treatment plant is diluted by adding water to it. Then it is released to ground (deep pits or dry wells), if the activity level is low.

In this method, there is a danger of contaminating ground water, if dilution is not adequate.

Another method is to fill the concentrated liquid in steel tanks and buried in ground. The leakage from these tanks is more dangerous for human and plant life. So, care should be taken to have leak proof tanks.

### 3. Gaseous Waste:

They do not require any treatment except filtration.

The gases are treated in a cleanup plant to remove radioactive iodine, which is more hazardous for human health.

The gaseous wastes are commonly diluted with air and after passing through, filter they are released to atmosphere through a high stack (chimney).

# DIESEL POWER PLANT

Power Plant Engineering

# Diesel Power Station:

***Working Principle: Diesel Engine***

- 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.

- The working fluid undergoes repeated thermodynamic cycle.

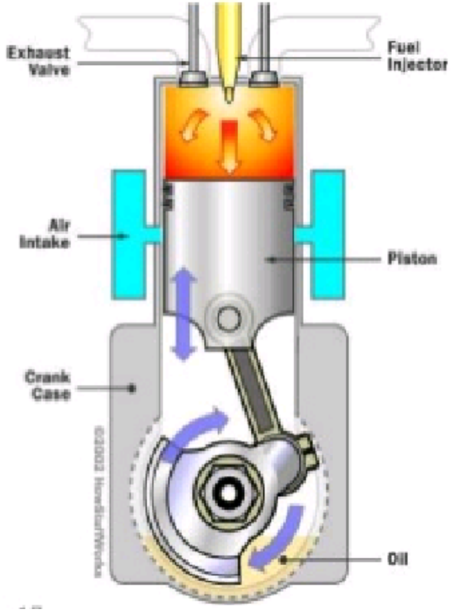
- A typical cycle has following distinct operations:

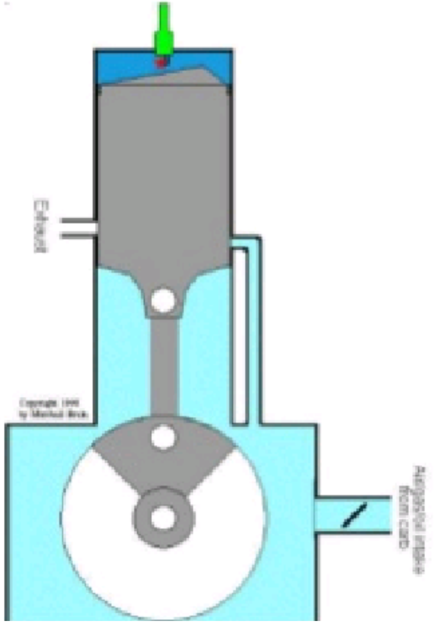
1. Cylinder is charged
2. Cylinder contents are compressed
3. Combustion (Burning) of charge, creation of high pressure pushing the piston and expansion of products of combustion.
4. Exhaust of spent products of combustion to atmosphere.

# Diesel Power Station:

## Two Stroke Cycle

A two-stroke, or two-cycle, engine is a type of internal combustion engine which completes a power cycle with two strokes (up and down movements) of the piston during only one crankshaft revolution.

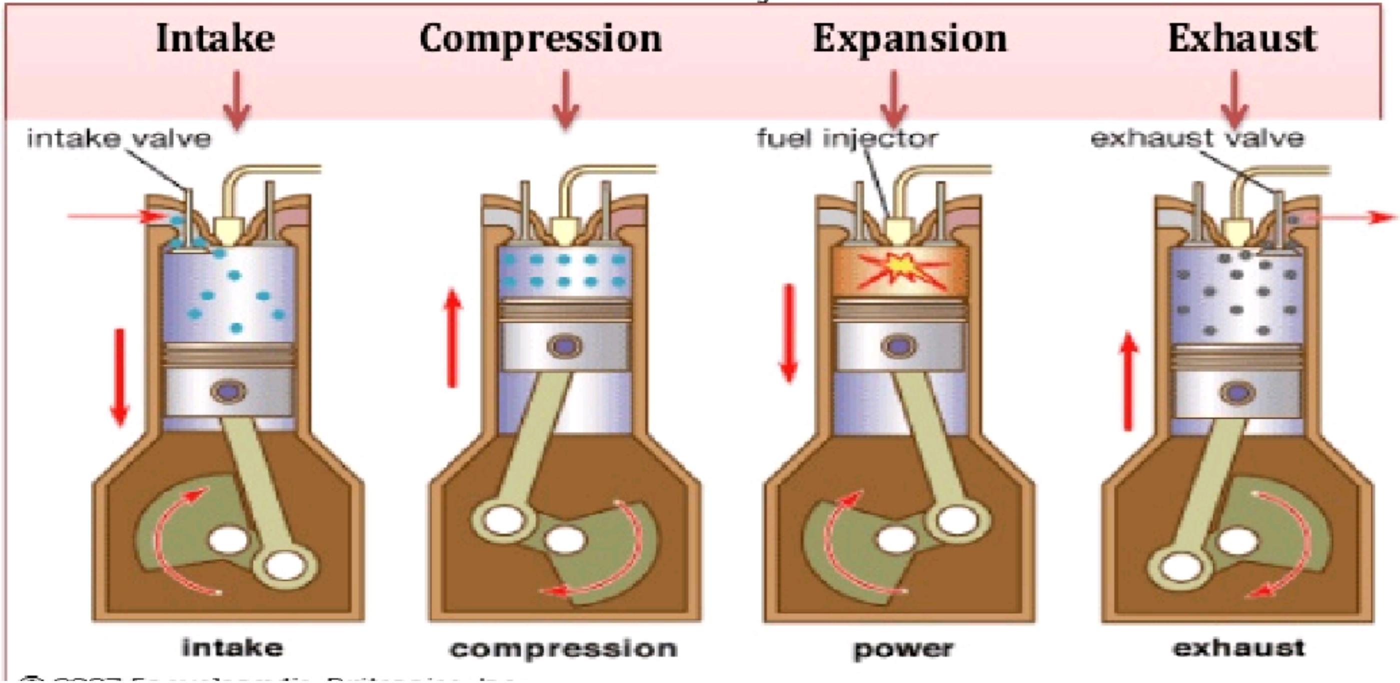


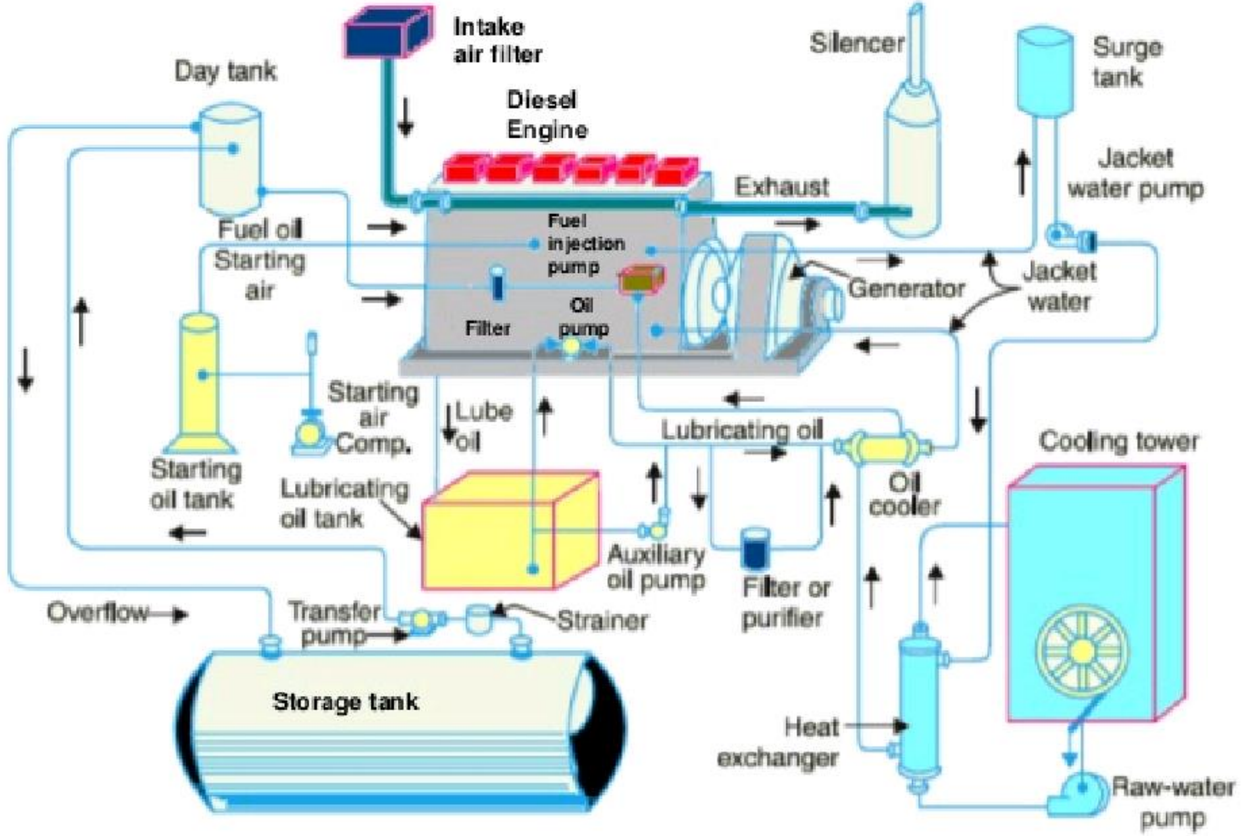



# Diesel Power Station:

**Diesel Engine: 1) Four Stroke 2) Two Stroke**

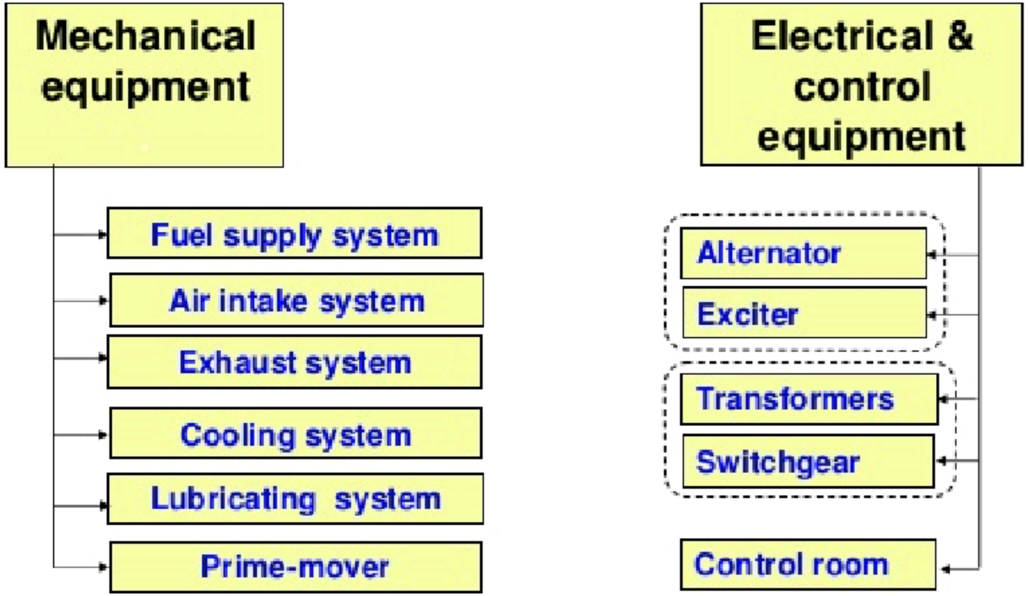
## Four Stroke Cycle



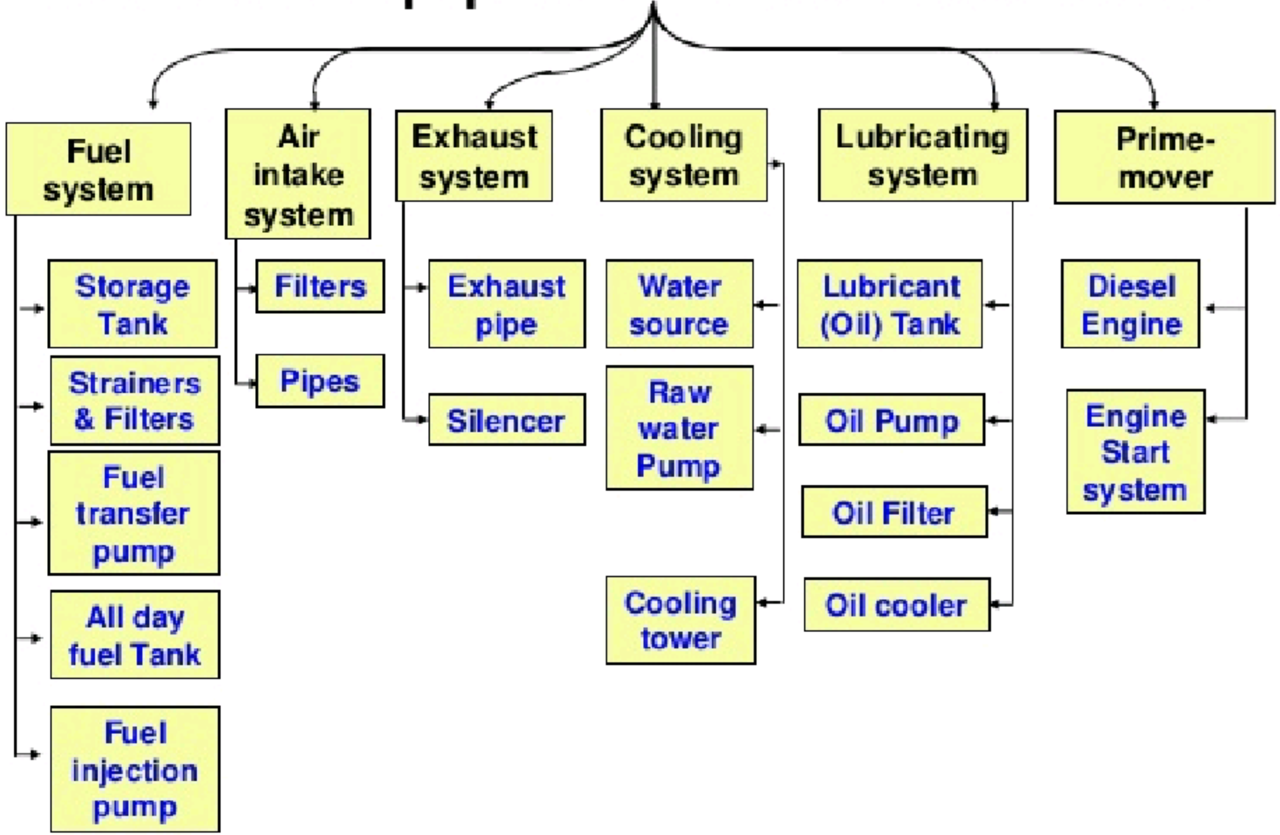



**Schematic arrangement of Diesel Power Plant**

# Equipment of Diesel Power Station



# Mechanical Equipment of Diesel Power Station

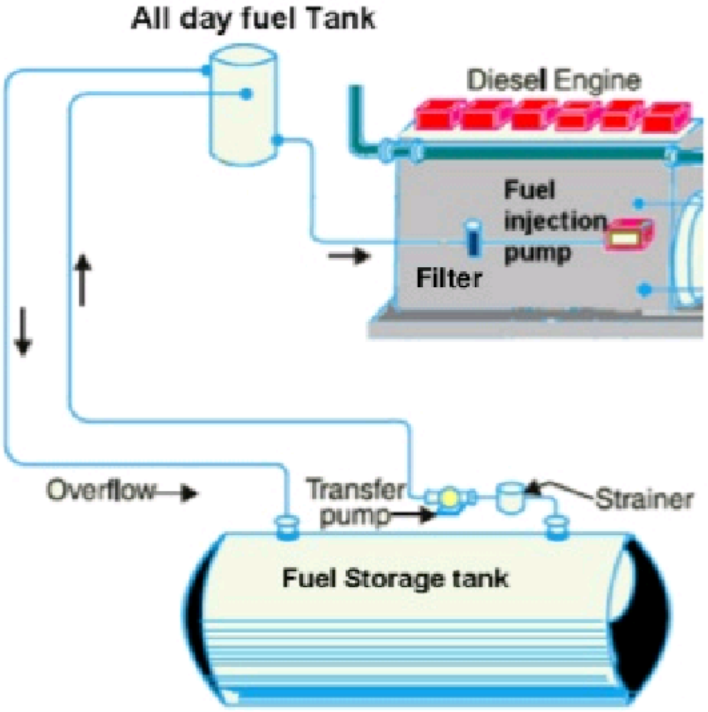


# Fuel supply system

It consists of storage tank, strainers, fuel transfer pump, all day fuel tank, filters and fuel injection pump.

Fuel is stored in a *storage tank* from which it is pumped through *strainer* by a *transfer pump* to a smaller *all day tank* at daily or short intervals.

From this tank, fuel oil is passed through *filters* to further remove suspended impurities. The clean oil is injected into the engine by *fuel injection pump*.

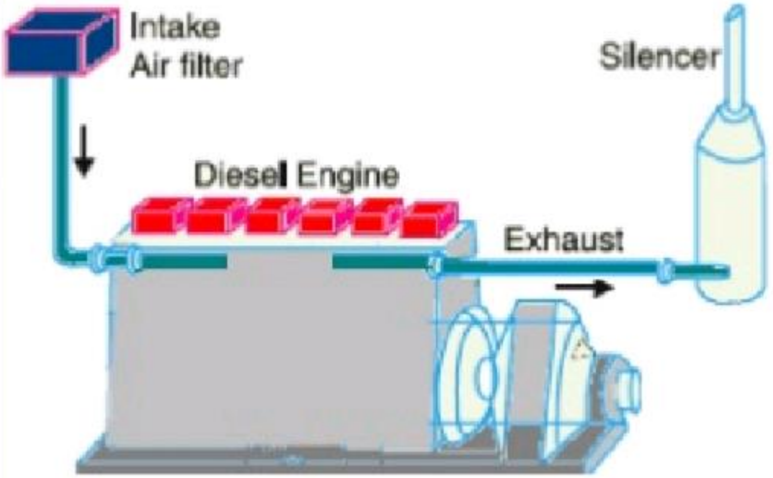


# Air intake & Exhaust systems

***Air intake system:***

-Supplies necessary air to the engine for fuel combustion. It consists of pipes for the supply of fresh air to the engine manifold.

-Filters are provided to remove dust particles from air which may act as abrasive in the engine cylinder.




***Exhaust system:***

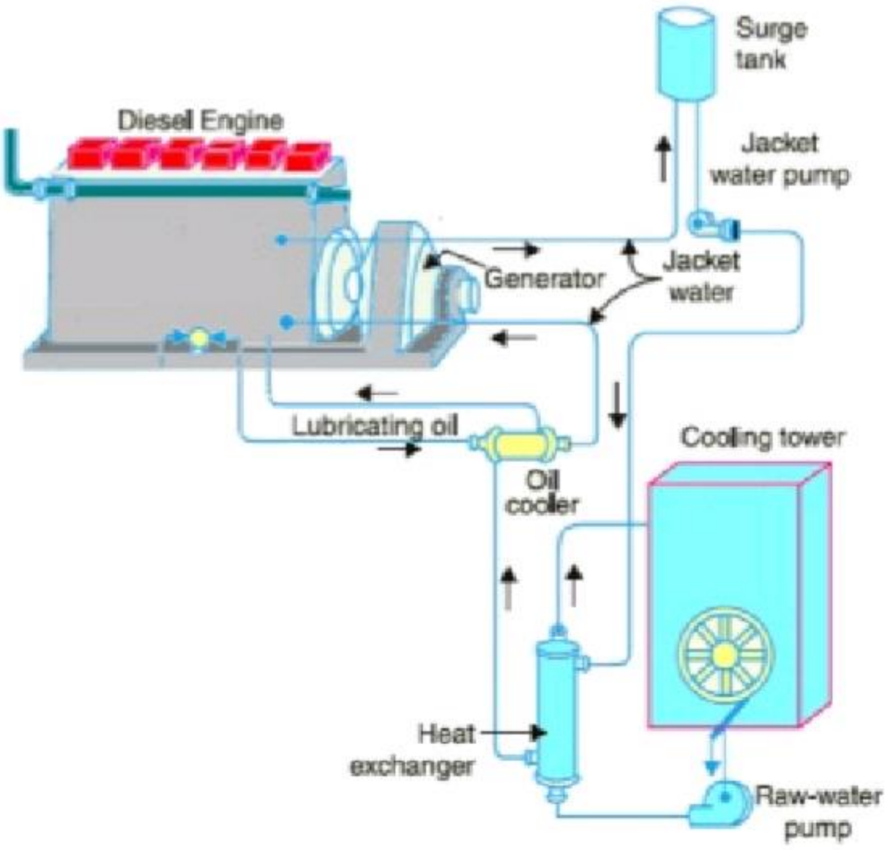
-Leads the engine exhaust gas outside the building and discharges it into atmosphere.

-A silencer is incorporated to reduce the noise level.

# Cooling system

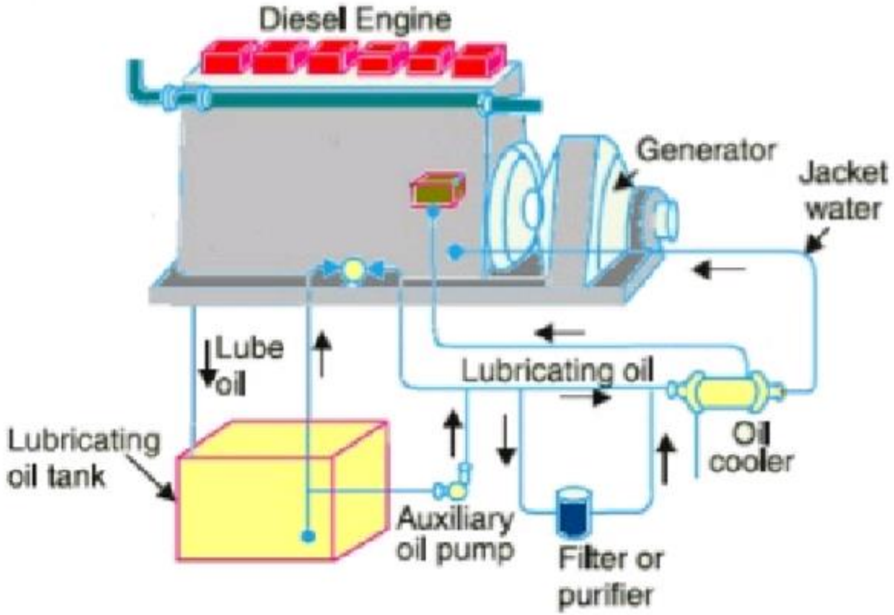
Part of heat released by fuel burning in the engine cylinder passes through the cylinder walls, piston, rings, ... etc. and may cause damage to the system. To keep the temperature of engine parts within safe operating limits, cooling is provided.

The cooling system consists of a *water source, pump and cooling towers*. The pump circulates water through cylinder and head jacket. The water takes away heat form engine and itself becomes hot. The hot water is cooled by cooling towers and is re-circulated for cooling.



# Lubricating system

- Comprises of *lubricating oil tank, pump, filter and oil cooler.*
- Minimizes wear of rubbing surfaces of the engine.
- Lubricating oil is drawn from the lubricating oil tank by the pump and is passed through filters to remove impurities.
- Oil coolers keep the temperature of the oil low.

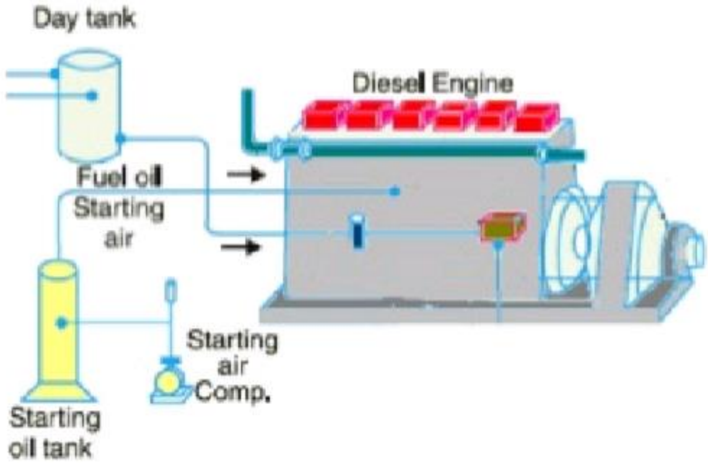


# Engine start system

- An arrangement to rotate the engine initially while starting, until firing starts and the unit runs with its own power.

- Small sets are started manually by handles.

**In larger units, *compressed air* is used for starting; air at high pressure is admitted to a few of the cylinders, causing them to act as reciprocating air motors to turn over the engine shaft. Fuel is admitted to the remaining cylinders which start the engine under its own power.**



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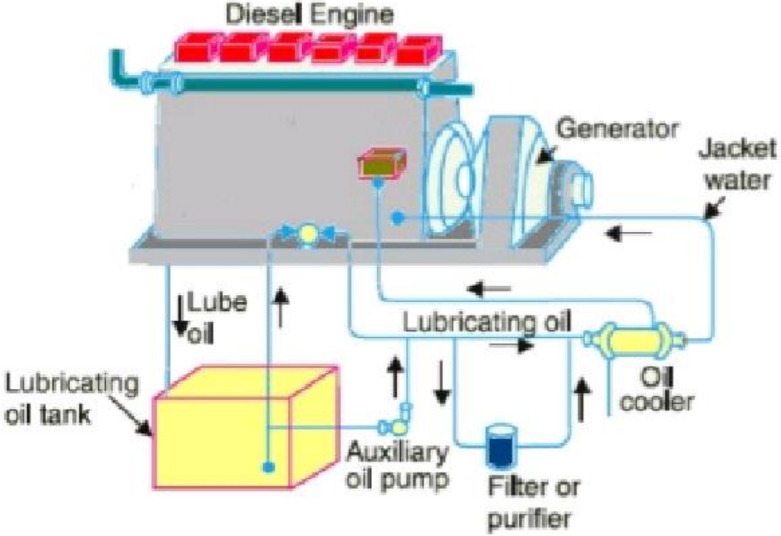

# Diesel Power Station:

***Advantages:***

1. The *design and layout* of the plant are *quite simple*.
2. It *occupies less space* as the number and size of the auxiliaries is small.
3. It can be *located at any place*.
4. It can *be started quickly* and can pick up load in a short time.
5. There are *no standby losses*.
6. It *requires less quantity of water* for cooling.
7. The *overall cost is much less* than that of steam power station of the same capacity.
8. The *thermal efficiency of the plant is higher* than that of a steam power station.

# Diesel Power Station:

***Disadvantages:***

1. The plant has *high running charges* as the fuel (i.e., diesel) used is costly.
2. The plant *does not work satisfactorily under overload conditions* for a longer period.
3. The plant can *only generate small power*.
4. The *cost of lubrication is generally high*.
5. The *maintenance charges are generally high*.