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# Nuclear powerplant

## Introduction :-

As large amount of coal and petroleum being used to produce energy, time may come when their resource may not be able to meet the energy requirement. Thus there is tendency to seek alternative source of energy the discovery that energy can be liberated by nuclear fission of materials like uranium(U), plutonium(Pu) has opened up a new sources power.

→ the heat produce due to fission of U and Pu is used to heat water to generate steam which is used for running turbo generator.

→ It has been found that one kg of U produce as much as energy of
∧ 45 00 ~~kg~~ tonnes of high grade coal.

Some factors which go infavour nuclear energy as follows

(i) Hydro-electric powerplant is a storage type and largely dependent on monsoon.

(ii) Oil is mainly needed for transportation fertilizers, and petrochemicals thus can't be used in large quantities.

(iii) coal is available in some parts of country and transportation of coal requires big investment.

(iv) Nuclear power is independent geographical factor, the only ~~reason~~ requirement is reasonably good supply of water. fuel transportation and large storage is not required and nuclear powerplant is a clean source of power

(v) Large quantity of energy released with consumption only a small amount of fuel.

## Advantages of Nuclear power plant

(i) It menimizes the ecological effect of power generation.

(ii) space requirement of a nuclear powerplant is less as compared to other conventional powerplant of equal size.

(iii) A nuclear powerplant consume very small quantity fuel. The fuel ~~consumption~~ transportation and large fuel ~~food~~ storage facilities are not needed.

(iv) There is increased reliability of operation

(v) Nuclear powerplant is not affected by adverse wrather condition

(vi) Material requirement on metal structures, piping, storage mechanism are much lower for a nuclear powerplant than a coal based power plant.

(vii) It doesnot require large quantity of water

## Disadvantage

(i) Intial cost of nuclear powerplant is higher as compared to hydro or steam power plant.

(ii) Nuclear powerplant are not well suited for varying load condition

(III) Radio active waste if not disposed carefully may have bad effect on the health of workers and other population

(IV) Maintenance cost of the plant is high.

(V) It requires trained personnel to handle nuclear power plant.

## Comparision with steam power plant

(i) The number of workman required for the operation of nuclear powerplant is much less than a steam powerplant. This reduces cost of operation

(II) The capital cost of nuclear power plant fall sharply if the size of the plant is increased. The

(III) capital cost such as structural materials, piping, storage mechanism etc. is much less in nuclear power plant than the steam power plant.

(III) There are no fuel transportation, handling and storage charges and also there is no problem of ash disposal.

(IV) Nuclear power plant occupies less space in comparision to thermal plants, thus civil construction cost is also less.

(V) The nuclear plant is more economical compared with thermal plant in areas which are remote from coal fields.

## Site selection :-

For establishing a nuclear powerplant, the following points have to be kept in view

### (i) Availability of water:-

At the powerplant site, an ample quantity of water should be available for cooling and make up water required for steam generation

### (ii) Distance from load centre

The plant should be located near the load centre. This will minimize the power loses in transmission lines

### (iii) Distance from populated area:-

The plant should be located far away from the populated area to avoid radioactive hazard.

### (iv) Accessibility to site:-

The powerplant should have rail and road transportation facilities.

### (v) Waste Disposal

The wastes of a nuclear powerplant are radio active and there should be sufficient space near the plant site for the disposal of the waste.

### (vi) safe guard against earthquakes:-

The site is classified into its respective seismic zone 1, 2, 3, 4 or 5. The zone 5 being the most seismic and unsuitable for nuclear powerplant. About 300 km of radius area around the proposed site is sailed for its past history of tremors.

(vii) Foundation condition

The substrata must be strong enough to support the heavy reactor which may weigh as 100,000 tons and imposed bearing pressure of around 50 tons per square meter.

## Nuclear Fuel

→ Nuclear fuel may be defined as a material in which the nuclei of the material undergo nuclear fission by nuclear bombardment and to produce a fission chain reaction.

→ It can be one or all of the following $U^{233}$, $U^{235}$ and $Pu^{239}$.

→ Natural uranium found in earth crust contains 3 isotopes namely $U^{234}$, $U^{235}$, $U^{238}$ and their percentage as follows

$U^{238}$ – 99.3%, $U^{235}$ – 0.7%, $U^{234}$ – Trace.

→ Out of these $U^{235}$ is most unstable and is capable of sustaining chain reaction and has been given name of primary fuel.

- $U^{233}$ and $Pu^{239}$ are artificially produced from $Th^{232}$ and $U^{238}$ respectively and called as Secondary fuel.

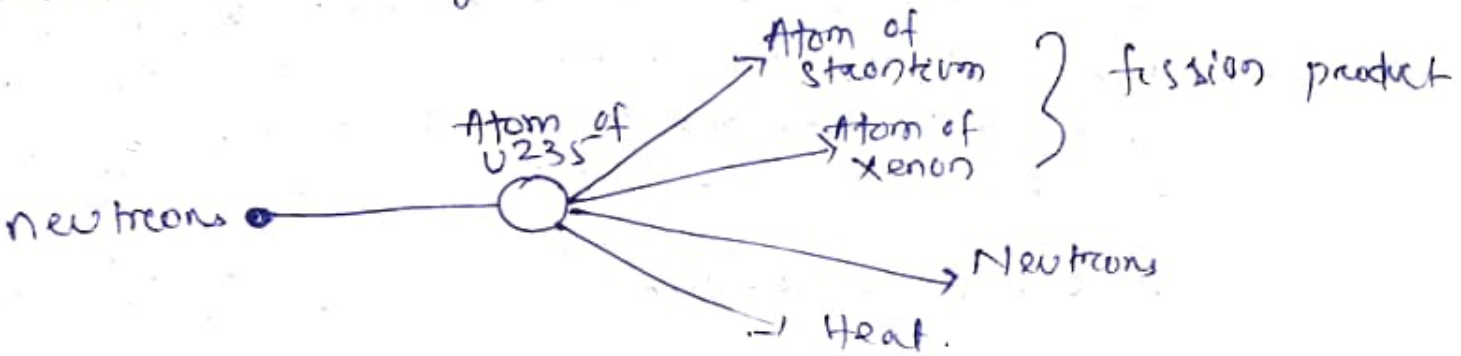
## Fertile fuel

It is defined as the material which absorbs neutron and undergoes spontaneous changes which lead to formation of fissionable material.

→ $U^{238}$ and $Th^{232}$ are fertile material, and they when absorb neutron, produces fissionable material $Pu^{239}$ and $U^{233}$ respectively

# Nuclear Fission

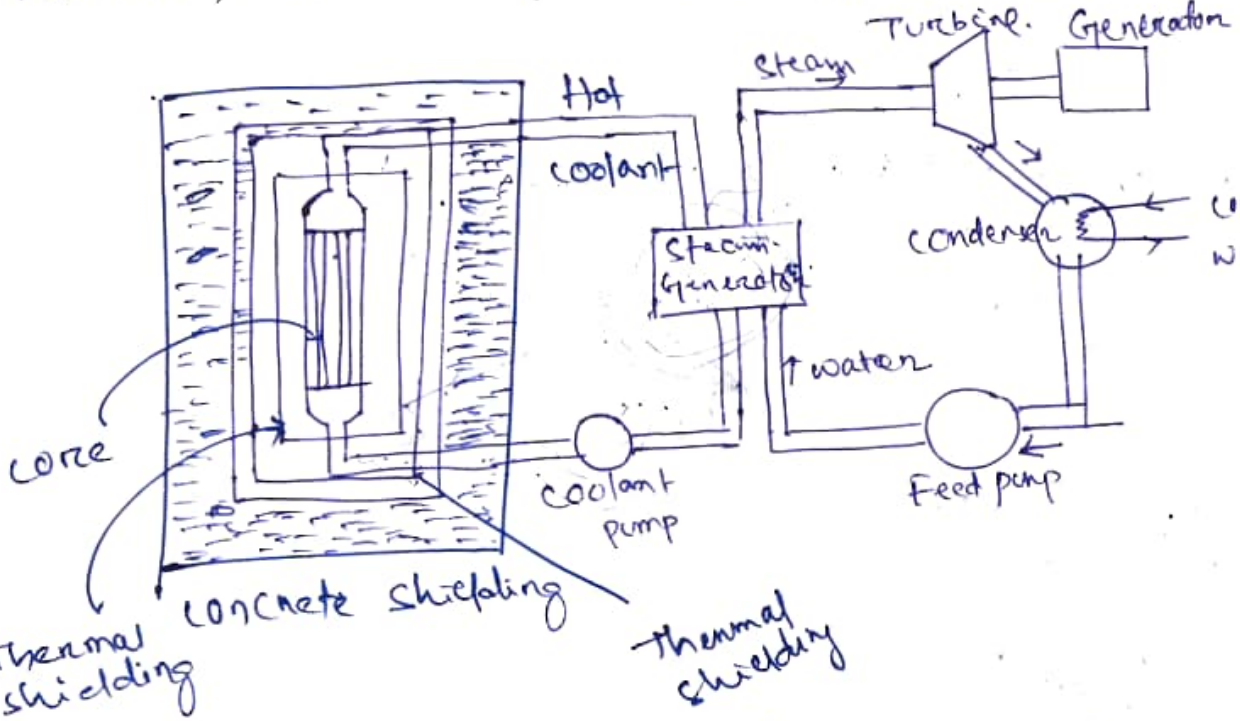
Nuclear fission is the process in which heavy nucleus is split when it is bombarded by certain particles. some of the isotopes of heaviest elements, $U^{235}$ $U^{233}$ and $Pu^{239}$ can upon absorbing neutron, be readily fission
→ this fission produce 2 or rarely 3, fragments moving at high speeds, two or ~~three neutrons~~ three neutrons and considerable energy.




→ Uranium exist as isotopes of $U^{238}$, $U^{234}$ and $U^{235}$, out of these isotopes U235 is most unstable. when a neutron is captured by a nucleus of an atom of $U^{235}$, it splits up roughly into two equal fragments and about 2-5 neutrons are released and a large amount of energy is produced. the neutrons so produced are very fast moving neutrons and can be made to fission other nuclei of U235 thus enabling a chain reaction to take place.

# Main components of a Nuclear power plant

The main component of a nuclear power plant are Nuclear reactor, heat exchanger (steam Generator), turbine, electric generator and condenser.




→ Reactor of Nuclear powerplant is similar to the furnace of the steam powerplant. The heat liberation in the reactor due to the nuclear fission of the fuel taken up by the coolant circulating through the reactor core.

→ Hot coolant leaves the reactor at top and then flows through the tubes of the ~~reactor core~~ of steam generator (boiler) and passes on its heat to the feed water.

→ Then the steam produced is passed through the turbine and passes on its heat to the feed water.

→ The steam produced is passed through the turbine and after work has been done by the expansion

of steam in the turbine, steam leaves the turbine and flows into the condenser. pumps are provided to maintain the flow of coolant, condensate and feed water

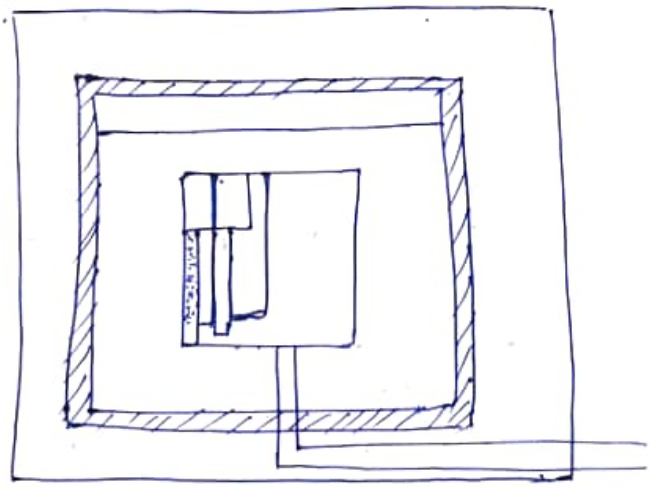
# Parts of Nuclear Reactor

A nuclear reactor is an apparatus in which heat is produced due to nuclear fission chain reaction.

- The parts of the nuclear reactor are

(I) Nuclear fuel (II) Moderator (III) control rods (IV) Reflector (V) Reactor vessel (VI) Biological shielding (VII) coolant.

→



i) Moderator

→ In the chain reaction the neutrons produced are fast moving neutrons. These fast moving neutrons are far less effective in causing the fission of $U^{235}$ and they to escape the reactor.

→ TO improve the utilization of these neutrons their speed is reduced. It is done by colliding

them with the nuclei of other material which is lighter, does not capture the neutrons but scatters them. Each such collision causes loss of energy and the speed of fast moving neutrons is reduced. such materials is called as moderator.

→ The slow neutrons so produced are easily captured by nuclear fuel and chain reaction proceeds smoothly. Graphite, heavy water and beryllium are used as moderator.

→ Reactors using enriched uranium does not require moderator but enriched uranium is costly due to processing needed.

A moderator should process following properties.

(I) It should have high thermal conductivity

(II) It should be available in large quantities in pure form

(III) It should provide good resistance to corrosion

(IV) It should stable under heat and radiation

(V) It should be able to slowdown neutrons.

(iii) Control rod

control rod are helpful in controlling the following functions

(i) To start the nuclear chain reaction when the reactor is started from cold.

(ii) The chain reaction should be maintained at steady condition at the required level

(iii) To shut down the reactor automatically under emergency condition.

→ The control and operation of nuclear reactor is different from fossil or fuel based furnace. In furnace is fed continuously and the heat in the is controlled by regulating fuel feed and combustion of air whereas the nuclear reactor contains as much fuel as is sufficient to operate large power plant for some months. The consumption of this fuel and power level of the reactor depends upon the neutron flux in the reactor core.

→ The energy produced in the reactor due to fission of nuclear fuel during chain reaction is so much that if it not controlled properly the entire core and surrounding structure may melt and radio-active fission product may come out from the reactor turn making it's unhabitable.

→ control rods are in the cylindrical or sheet form are made of boron or cadmium. These rods can be moved in and out of the holes in the reactor core assembly. Their insertion absorbs more neutrons and damps down the reaction and their withdrawal absorbs less neutrons. Thus power of reaction is controlled by shifting control rods which may be done manually or automatically.

control rod should poneses following properties.

(i) They should have adequate heat transfer properties

(ii) They should be stable under heat and radiation

(iii) The should be corrosion resistant

(iv) The should have sufficient cross sectional area for the absorption

## Reflector

The neutrons produced during the fission process will be partly absorbed by the fuel rods, moderator, coolant or structural material etc.

~~The unal neutrons which are not~~

→ the unabsorbed neutron will try to leave the reactor core never to return to it and will be lost. such losses should be minimised.

It is done by surrounding the reactor core by a material called reflector which will send the neutrons back into the core. These neutrons can then cause more fission and improve

the economy of the reactor

## Reactor vessel / pressure vessel

It is a strong walled container housing the core of the power reactor. It contains moderator, reflector, thermal shielding and control rods.

## Biological shielding

shielding the radio-active zones in the reactor from possible radiation hazard is essential to protect the operating men from harmful effects.

→ During fission reaction, alpha, beta particles, gamma deadly particles and neutrons are produced. Out of these neutrons and gamma rays are of main significance. A protection must be provided against them.

→ Thick layers of lead or concrete are provided all around the reactor for stopping the gamma rays.

## coolant

→ ~~coolants~~ coolant flows through and around the reactor core. It is used to transfer the large amount of heat produced in the reactor core during chain reaction. The coolant either transfers heat to another medium or of the coolant used ~~as~~ water it takes up the heat and gets converted into steam in the reactor which is directly sent to the turbine.

→ The various coolant used are (light water, heavy water) gas (Air, $CO_2$, hydrogen, helium) and liquid metal such as sodium or mix of sodium & potassium

## (3) Rawatbhata (Rajasthan) Atomic power station

- It has been built at about 65 Km South-west Kota in Rajasthan on the right bank of Rana Pratap Sagar dam on Chambal river with Canadian collaboration.

- It has 2 reactor each of 200mw capacity and uses natural uranium in the form oxide as fuel and heavy water as moderator.

## (5) Kalpakkam Nuclear power-station

- It is the 3rd nuclear powerstation of India built about 60Km from Chennai. It has been designed and constructed by Indian scientist and engineers.
- It has 2 reactor each 235 mw capacity and uses natural uranium as fuel.

## (4) Narora nuclear power-station

- This is the 4th nuclear power-station of India and is built at Narora at Bulandshahar District of Uttar pradesh.
- This plant has 2-reactor of (CANDU- PHW (Canadian-deutrium-uranium pressurised heavy water) System and uses natural uranium as fuel. This plant is wholly designed and constructed by Indian scientist and engineers.

## (5) Kakrapar nuclear powerplant

This is the 5th nuclear powerplant of India and is located at Kakrapur near sonat in Gujarat.

- This power station have 2-reacton each of 235 MW capacity. The reacton constructed at Kakrapar are of candu type. natural uranium fuelled and heavy water as moderator.

## (6) Kaiga atomic power plant

- It is the 6th atomic powerplant located on left bank of Kali river at Kaigad in Karnataka.
- It has 2 reacton each 235 MW. This nuclear reacton is candu type reacton, these reacton have modern ~~traffic~~ system to prevent accident.