SNS COLLEGE OF TECHNOLOGY

Powerplant Engineering

Unit IV

Nuclear Power Plants

Nuclear energy

- The energy released during nuclear fission or fusion, especially when used to generate electricity.

Nuclear Materials

Nuclear material refers to the metals uranium, plutonium, and thorium.

Uranium-233, and enriched uranium (U-235)

- -Working principle :

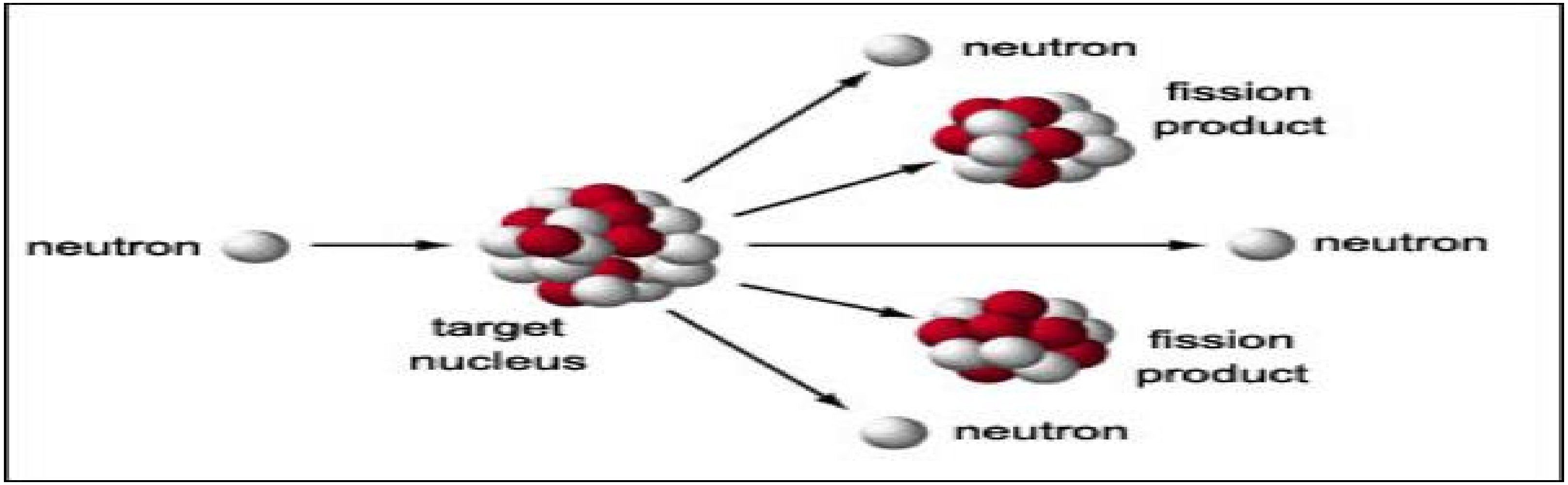
A nuclear power plant works in a similar way as a thermal power plant. The difference between the two is in the fuel they use to heat the water in the boiler(steam generator).

Inside a nuclear power station, energy is released by nuclear fission in the core of the reactor.

1 kg of Uranium U^{235} can produce as much energy as the burning of 4500 tonnes of high grade variety of coal or 2000 tonnes of oil.

Nuclear fission

- **Nuclear fission** is either a nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts (lighter nuclei). The fission process often produces free neutrons and gamma photons, and releases a very large amount of energy even by the energetic standards of radioactive decay.



- It is a process of splitting up of nucleus of fissionable material like uranium into two or more fragments with release of enormous amount of energy.
- The nucleus of U^{235} is bombarded with high energy neutrons

$$U^{235} + {}_0n^1 \longrightarrow Ba^{141} + Kr^{92} + 2.5\,{}_0n^1 + 200 \text{ MeV energy.}$$

- The neutrons produced are very fast and can be made to fission other nuclei of U^{235}, thus setting up a chain reaction.
- Out of 2.5 neutrons released one neutron is used to sustain the chain reaction.

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ joule.}$$
$$1 \text{ MeV} = 10^6 \text{ eV}$$

- U^{235} splits into two fragments (Ba^{141} & K^{92}) of approximately equal size.
- About 2.5 neutrons are released. 1 neutron is used to sustain the chain reaction.
- 0.9 neutrons is absorbed by U^{238} and becomes Pu^{239}.
- The remaining 0.6 neutrons escapes from the reactor.
- The neutrons produced move at a very high velocity of 1.5×10^{7} m/sec and fission other nucleus of U^{235}. Thus fission process and release of neutrons take place continuously throughout the remaining material.
- Alarge amount of energy(200 Million electron volts, Mev) is produced.

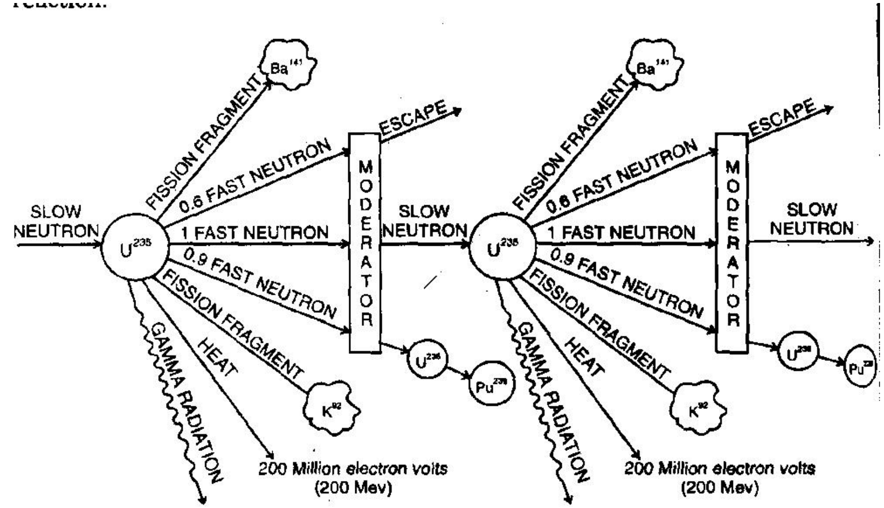
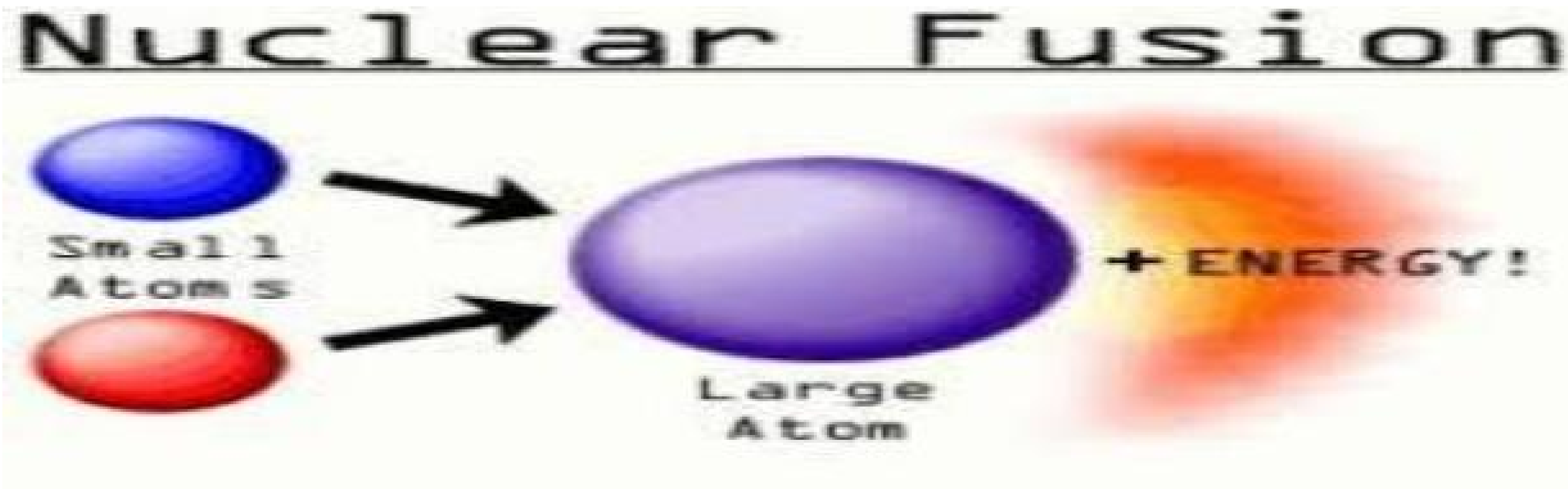


Fig. 3.7: CONTROLLED CHAIN REACTION IN A NUCLEAR REACTOR

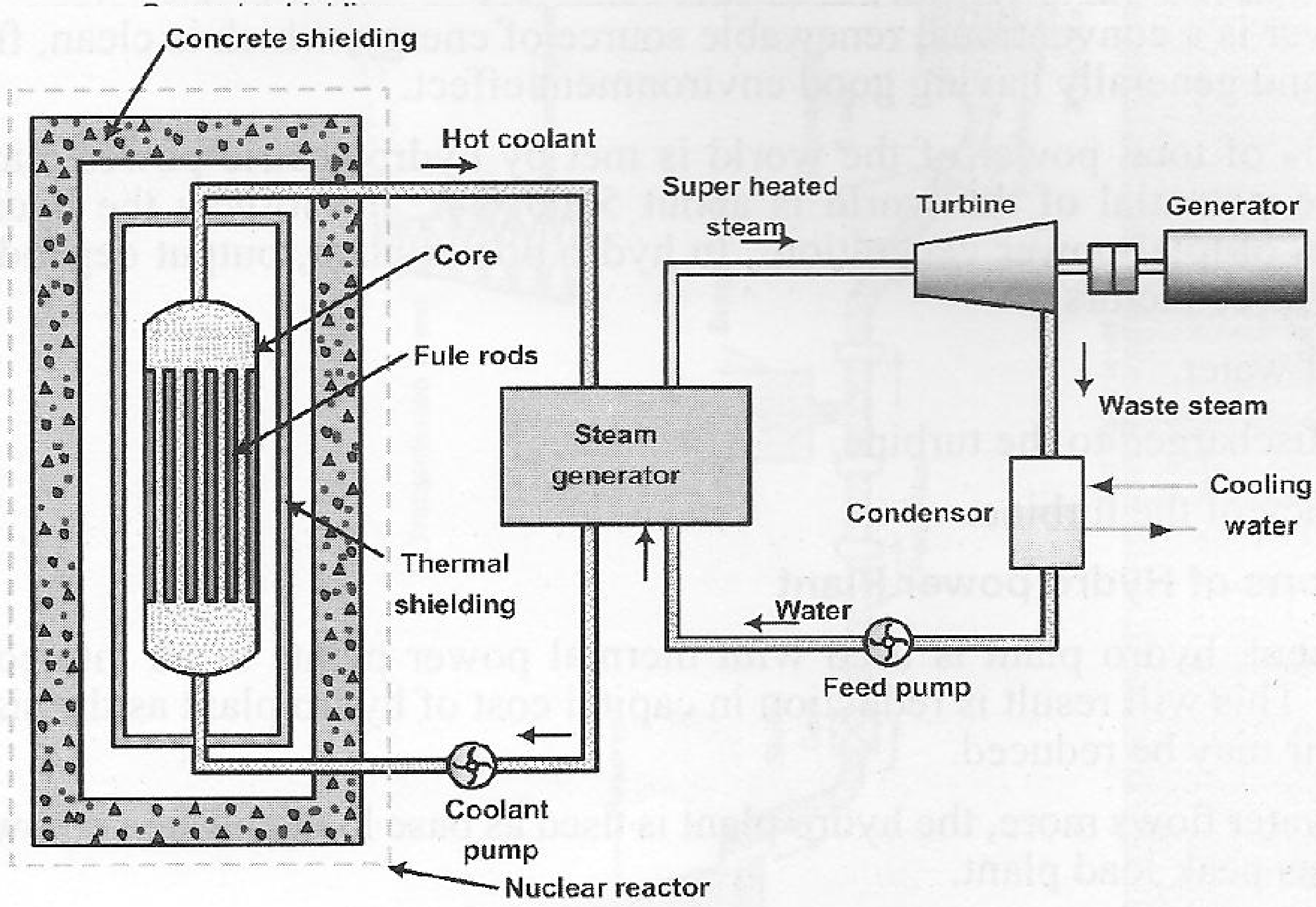
Moderators- Slow down the neutrons from high velocities but not absorb them

Nuclear fusion

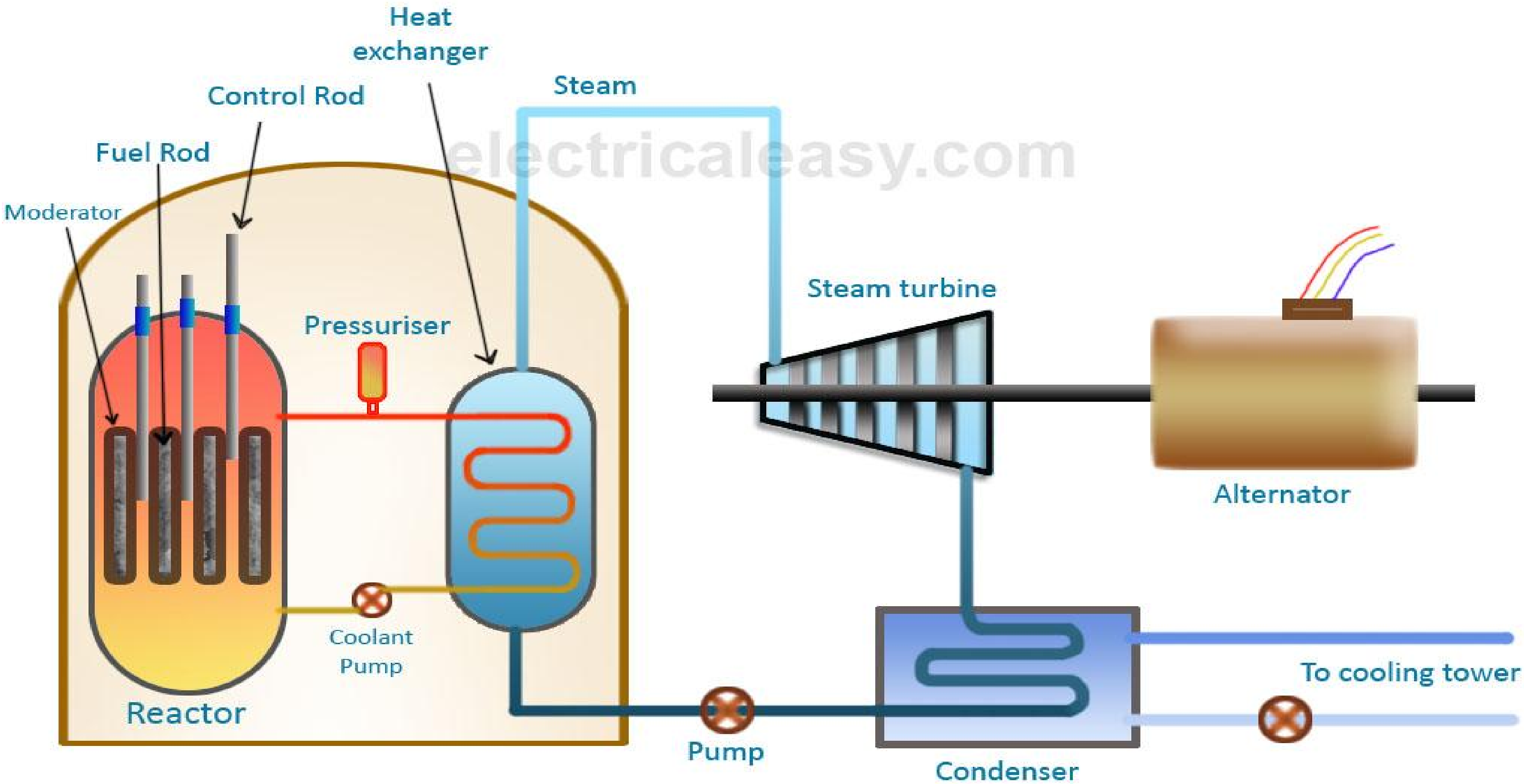
- **Nuclear fusion** is a reaction in which two or more atomic nuclei come close enough to form one or more different atomic nuclei and subatomic particles (neutrons or protons). The difference in mass between the reactants and products is manifested as the release of large amounts of energy.



Layout of Nuclear Power Plant



Layout of Nuclear Power Plant



Components

- **Components**

1. Reactor core(Fuel rods)
2. Reflector
3. Control mechanism
4. Moderator
5. Coolants
6. Measuring instruments
7. Shielding

- Nuclear Reactor

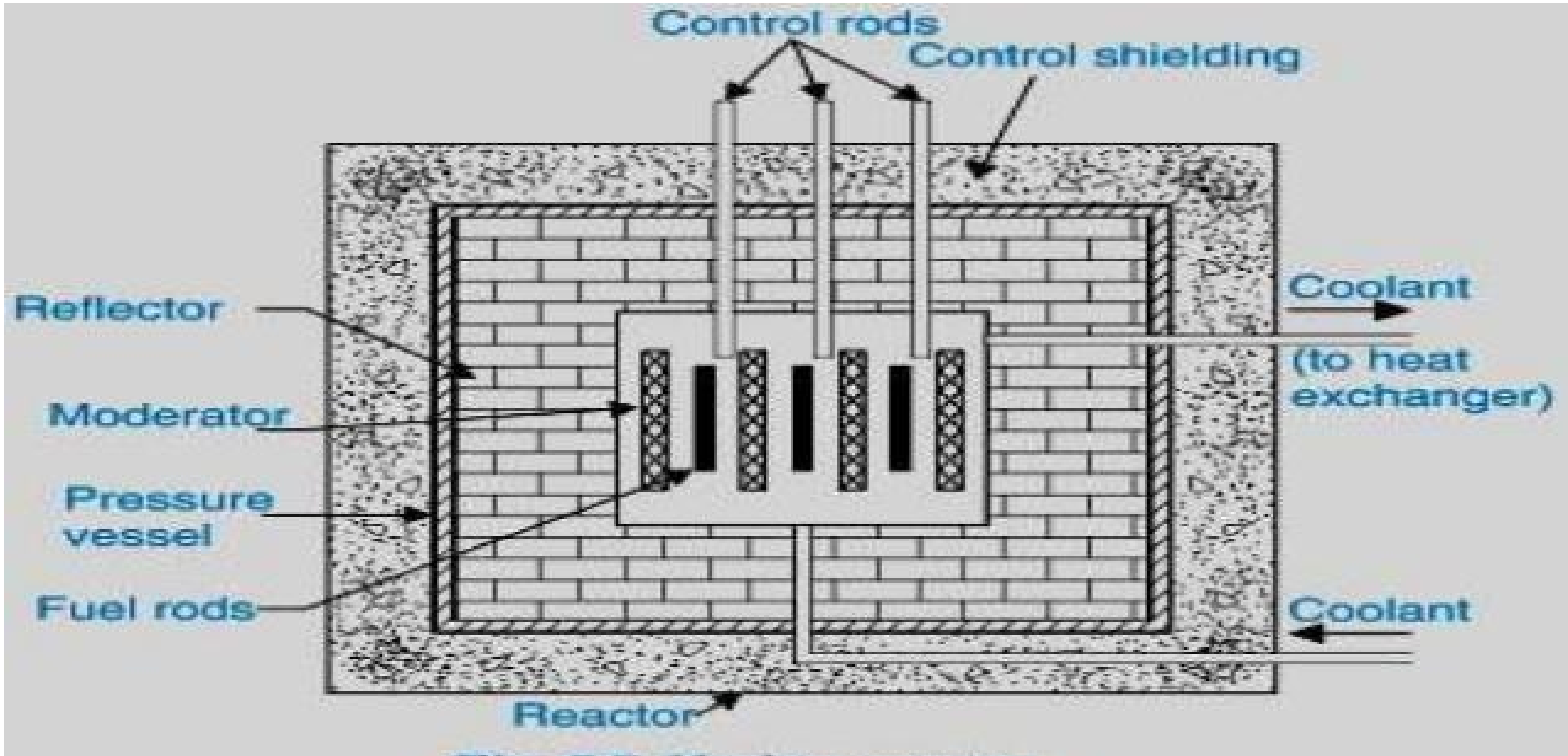


Fig. 7.7. Nuclear reactor.

•**Reactor Core :** This is the main part of reactor which contain the fissionable material called **reactor fuel.** *Fission energy is liberated in the form of heat for operating power conversion equipment.* The fuel element are made of plate of rods of uranium.

- **Reactor Core** **Where the nuclear fission process takes place.**

•**Reactor reflector :**The **region surrounding the reactor core** is known as **reflector.** Its function is to **reflect** back some of the **neutron** that **leak** out from the surface of core.

- **Control rods :** The rate of reaction in a nuclear reactor is controlled by control rods. Since the neutron are responsible for the progress of chain reaction, suitable neutron absorber are required to control the rate of reaction.
- **For starting the reactor**
- **To keep the production at a steady state**
- **For shutting down the reactor under normal or emergency conditions**
  - ❖ **Cadmium** and **Boron** are used as control rods.

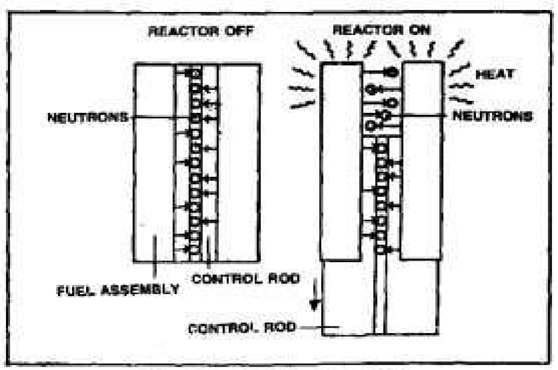


Fig. 3.8: CONTROL RODS

Control rods limit the number of fuel atoms that can split. They are made of boron or cadmium which absorbs neutrons

- **Moderator :**The function of a reactor is to **slow down thefast neutron**. The moderator should have
  - **High slowing down power**
  - **Non corrosiveness**
  - **High melting point for solids and low melting point for liquids.**
  - **Chemical and radiation stability.**
  - **High thermal conductivity**
  - **Abundance in pure form.**
- **Moderator : This reduces the speed of fast moving neutrons.**
- **The commonly used moderator are :**
  - **Ordinary water**
  - **Heavy water**
  - **Graphite.**

- **Coolant :**The material used to **carry the intense heat generated** by fission as fast as liberated is known as **reactor coolant.** The coolant generally pumped through the reactor in the form of liquid or gas. It is circulated throughout the reactor so as to maintain a uniform temperature.

- **Measuring Instruments:** Main instrument required is for
- the purpose of measuring **thermal neutron flux** which **determines the power developed by the reactor.**

- **Shielding:** The large steel recipient containing the core, the control rods and the heat-transfer fluid.

•All the components of the reactor are container in a solid concrete structure that guarantees further isolation from external environment. This structure is made of **concrete that is one-metre thick, covered by steel.**

- -Advantages of Nuclear power plant:

Space required is less when compared with other power plants.

Nuclear power plant is the only source which can meet the increasing demand of electricity at a reasonable cost.

A nuclear power plant uses much less fuel than a fossil-fuel plant.

•1 metric tonne of uranium fuel = 3 million metric tonnes of coal = 12 million barrels of oil.

- -Disadvantages of Nuclear power plant:

- Radioactive wastes must be disposed carefully, otherwise it will adversely affect the health of workers and the environment as a whole.
- Maintenance cost of the plant is high.

- Nuclear waste

  They are highly radioactive

  Many of them have very long half-lives.
- Radioactive waste must be stored carefully.

- Low level radioactive waste

  cooling water pipes, radiation suits, etc.

  stored in storage facilities

  radioactivity will fall to a safe level after 10 to 50 years.

- High level radioactive waste

  used nuclear fuel

  highly radioactive

  embedded in concrete and stored deep underground for several thousand years

Selection of Site

- Availability of water - NPP requires ample amount of water for cooling and steam generation.
- Disposal of Waste – Dangerous waste/residue obtained

  It needs to be disposed deep under the ground in sea so that radioactive effect is eliminated.
- Away from populated area – For health safety
- Nearest to the load centre
- Other Factors – Accessibility to the road and rail are general considerations.

Thank u