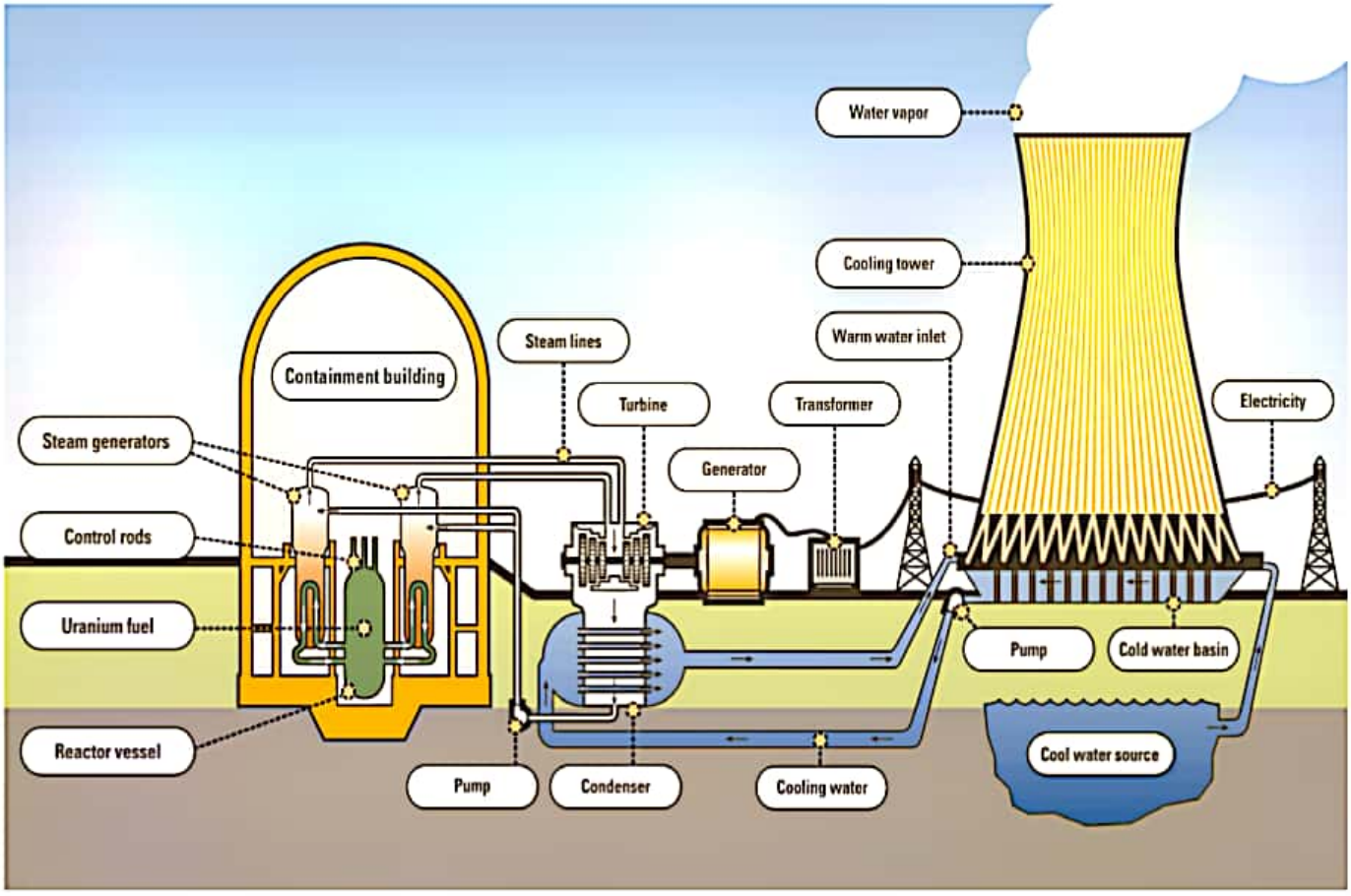
NUCLEAR POWER PLANT



INTRODUCTION OF THE TOPIC: NUCLEAR POWER PLANT:-

WHY? NUCLEAR POWER PLANT:

In previous chapters, we studied how electricity produced with the help of water & coal (known as Hydro & Thermal Power Plant). But, now a day's our population as well as industrial sector increases, it means that demand of electrical power increases day by day. To fulfill this demand water & coal is of limited edition, so we required searching newly source of energy for production & fulfilment of electrical demand.

To overcome the above mentioned problem, nuclear energy is a best solution to produce huge amount of electrical energy. With the fission process, we have to produce this energy. This topic is similar to thermal
power plant, in thermal power, coal is used to produce heat energy on the other hand in nuclear heat energy is produced with fission process of uranium, thorium & plutonium.

DEFINITION OF NUCLEAR POWER PLANT:

The Power Plant which uses nuclear energy of radioactive material (Uranium or Thorium) converted into Electrical Energy is known as Nuclear Power Plant.

BASIC PRINCIPAL OF NUCLEAR POWER PLANT:

Every power plant has its own basic principal, on the basis of this the plant works. The Basic Principal of Nuclear Power Plant is given below:

CE↔HE ↔KE ↔ME ↔EE

As we know that, the freely moving neutrons bombarded with radioactive material (U235 or Th232) the heat energy produced, with the help of this heat energy & water a steam produced at high pressure & temperature. High pressure steam passes towards turbine where KE is converted to ME. We know that, turbine & generator are mechanically coupled through this combination an Electrical Energy is produced in Nuclear Power Plant.

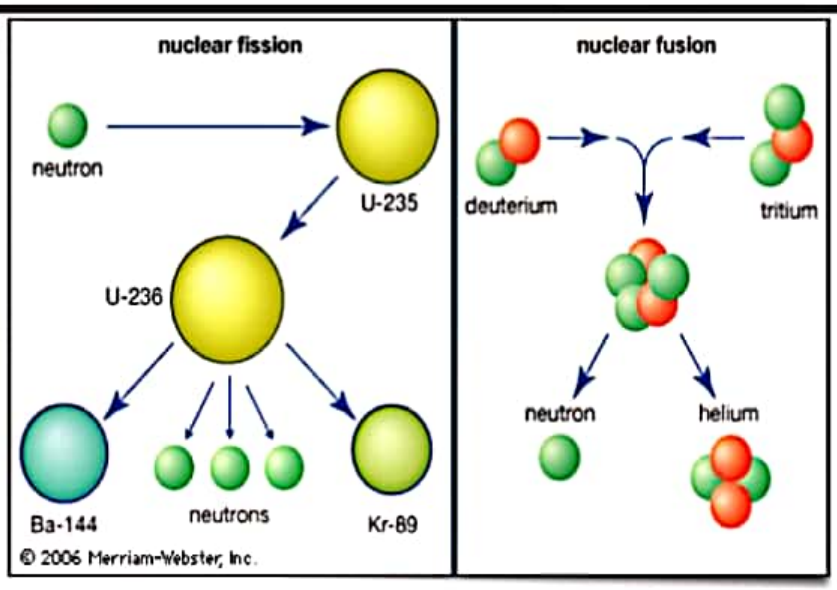
LIST OF NUCLEAR POWER PLANT IN MAHARASHTRA & INDIA WITH THEIR INSTALLED CAPACITIES:

1. State the nuclear power plant in Maharashtra with their installed capacity?
2. State the nuclear power plant in India with their installed capacities?
3. List any FOUR nuclear power stations in India with their generating capacity?
4. List out any TWO nuclear power stations in India with Capacity.
5. State locations of any four nuclear power plants in India.

FACTORS GOVERNING SELECTION OF SITE FOR THE NUCLEAR POWER PLANT

1. Availability of water: sufficient supply of neutral water is obvious for generating steam & cooling purposes in nuclear power station.
2. Disposal of Waste: The wastes of nuclear power station are radioactive and may cause severe health hazards. Because of this, special care to be taken during disposal of wastes of nuclear power plant. The wastes must be buried in sufficient deep from earth level or these must be disposed off in sea quite away from the sea share.
3. Distance from Populated Area: As there is always a probability of radioactivity, it is always preferable to locate a nuclear station sufficiently away from populated area.
4. Transportation Facilities: During commissioning period, heavy equipment to be erected, which to be transported from manufacturer site.So good railways and road ways availabilities are required.
5. Skilled Person Requirement: For availability of skilled manpower to run & handle the plant also good public transport should also be present at the site.
6. Near to Load Centre: As we know that generating stations are far away from thickly populated area, so to reduce the transmission & distribution losses the plant should located near to load centre.
7. Storage of Nuclear Material: the nuclear materials are radioactive, which are dangerous to health to overcome this drawback a separate arrangement provided for storage of material.
8. Geographical Condition: the radioactive material are very dangerous to human health & all living organisms, if due to earthquake chances occurs to blast the reactors to avoided this the area should be free from earthquake.

NUCLEAR FISSION VS. NUCLEAR FUSION



Top: Uranium-235 combines with a neutron to form an unstable intermediate, which quickly splits into barium-144 and krypton-89 plus three neutrons in the process of nuclear fission. Bottom: Deuterium and tritium combine by nuclear fusion to form helium plus a neutron.

NUCLEAR FISSION VS NUCLEAR FUSION

Nuclear fusion and **nuclear fission** are two different types of energy-releasing reactions in which energy is released from high-powered atomic bonds between the particles within the nucleus. The main difference between these two processes is that **fission is the splitting of an atom into two or more smaller ones** while **fusion is the fusing of two or more smaller atoms into a larger one.**

	Nuclear Fission	Nuclear Fusion
Definition:	Fission is the splitting of a large atom into two or more smaller ones.	Fusion is the fusing of two or more lighter atoms into a larger one.
Natural occurrence of the process:	Fission reaction does not normally occur in nature.	Fusion occurs in stars, such as the sun.
Byproducts of the reaction:	Fission produces many highly radioactive particles.	Few radioactive particles are produced by fusion reaction, but if a fission "trigger" is used, radioactive particles will result from that.
Conditions:	Critical mass of the substance and high-speed neutrons are required.	High density, high temperature environment is required.
Energy Requirement:	Takes little energy to split two atoms in a fission reaction.	Extremely high energy is required to bring two or more protons close enough that nuclear forces overcome their electrostatic repulsion.
Energy Released:	The energy released by fission is a million times greater than that released in chemical reactions; but lower than the energy released by nuclear fusion.	The energy released by fusion is three to four times greater than the energy released by fission.
Nuclear weapon:	One class of nuclear weapon is a fission bomb, also known as an atomic bomb or atom bomb.	One class of nuclear weapon is the hydrogen bomb, which uses a fission reaction to "trigger" a fusion reaction.

NUCLEAR FUELS:

Q.1) what are the different fuels used in nuclear power plant? Write in short?
Q.2) state any two fuels used in nuclear power plant?

In Nuclear Power Plant for the Production of heat energy Uranium, thorium & plutonium fuels are used.

A. URANIUM & ITS PROPERTIES:

Atomic Number: 92
Melting Point: 1408 K (1135°C or 2075°F)
Boiling Point: 4404 K (4131°C or 7468°F)
Uranium is a very important element because it provides us with nuclear fuel used to generate electricity in nuclear power stations. Naturally occurring uranium consists of 99% uranium-238 and 1% uranium-235. Uranium-235 is the only naturally occurring fissionable fuel (a fuel that can sustain a chain reaction).

B. NATURAL URANIUM: it consists of 0.714% of & 99.28% .
C. ENRICHED URANIUM: The Process used to increase the percentage of 235-U is known as enrichment. This will help us to maintain chain reaction. Normally it contains higher percentages (3 to 4%) of 235-U.

PLUTONIUM: Due to the absorption of neutrons without fusion in & the plutonium is formed. Atomic Number: 94,Melting point: 641 °C, Boiling point: 3232 °C

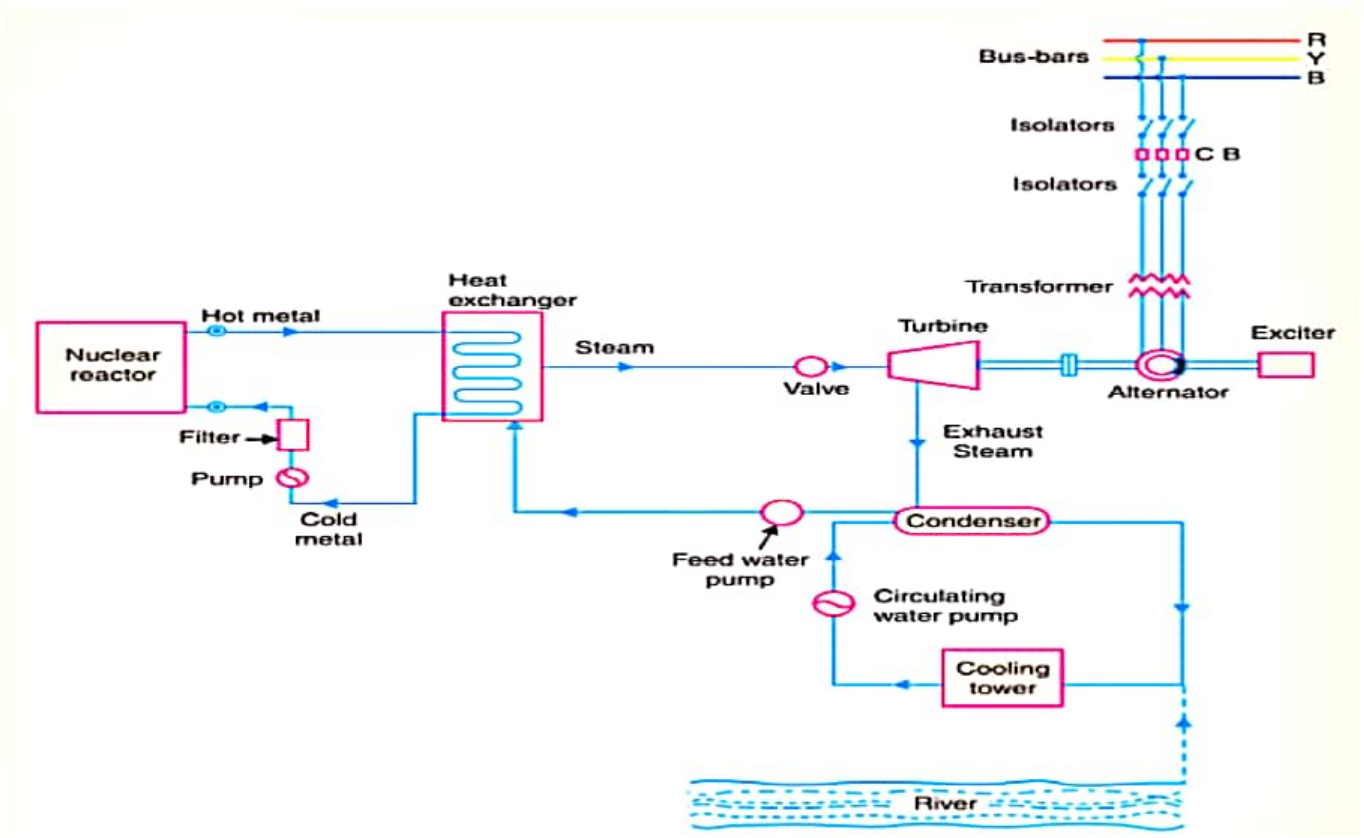
D. URANIUM OXIDE: it is also formed due to enrichment process, but it is in brittle & produced in the form of powder.

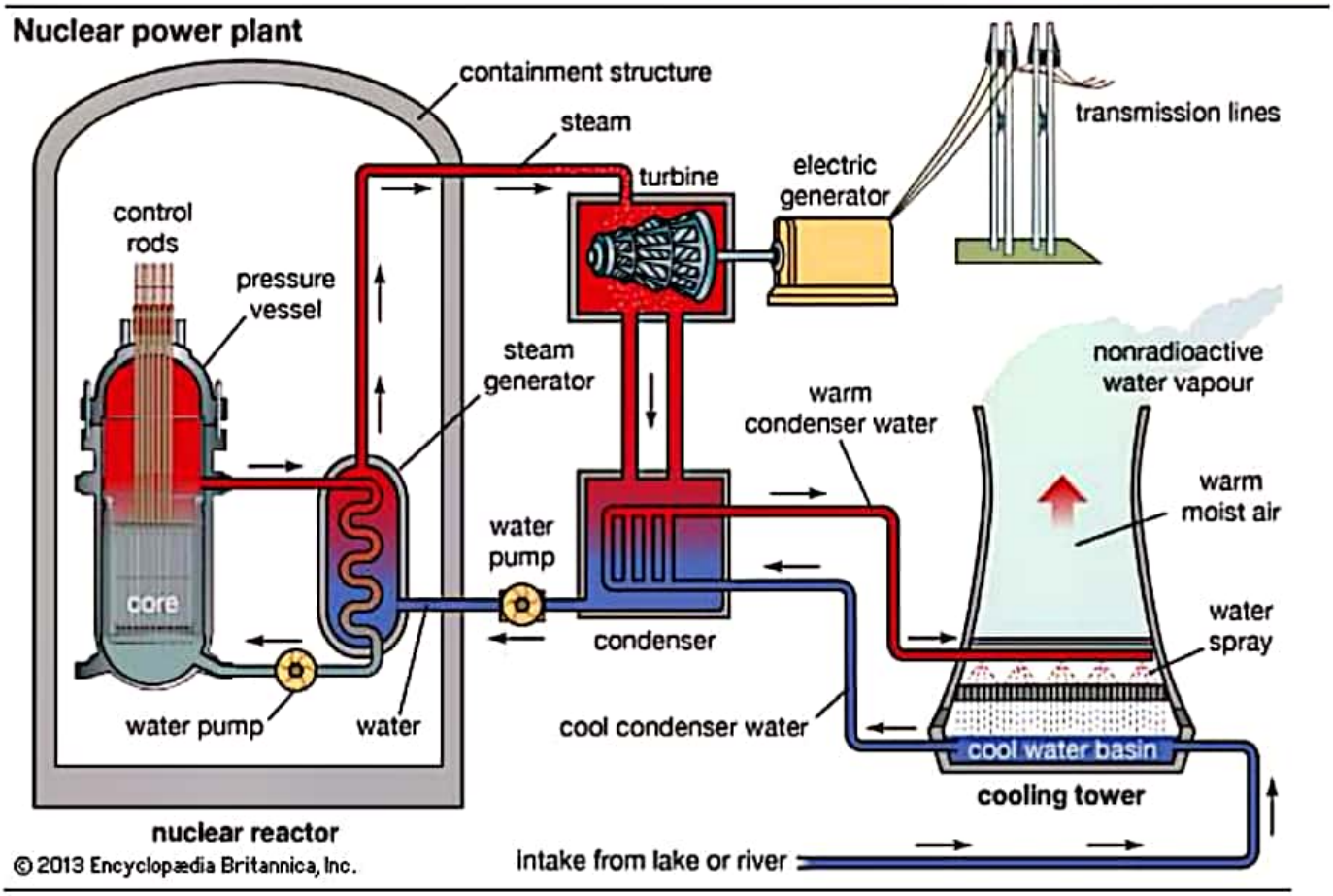
E. URANIUM CARBIDE: this material is not economical in use, but it has very good properties to use as nuclear fuel.

F. THORIUM & ITS PROPERTIES:

Atomic Number: 90
Melting Point: 1750 0c
Boiling Point: 4790 0c
A weakly radioactive, silvery metal. Before it uses of Thorium first up all converted into Thorium is weakly radioactive: all its known isotopes are unstable, with the six naturally occurring ones (thorium-227, 228, 230, 231, 232, and 234). India and China are in the process of developing nuclear power plants with thorium reactors, but this is still a very new technology. Thorium has higher cost that's why it is not popular.

SCHEMATIC ARRANGEMENT OF NUCLEAR POWER PLANT





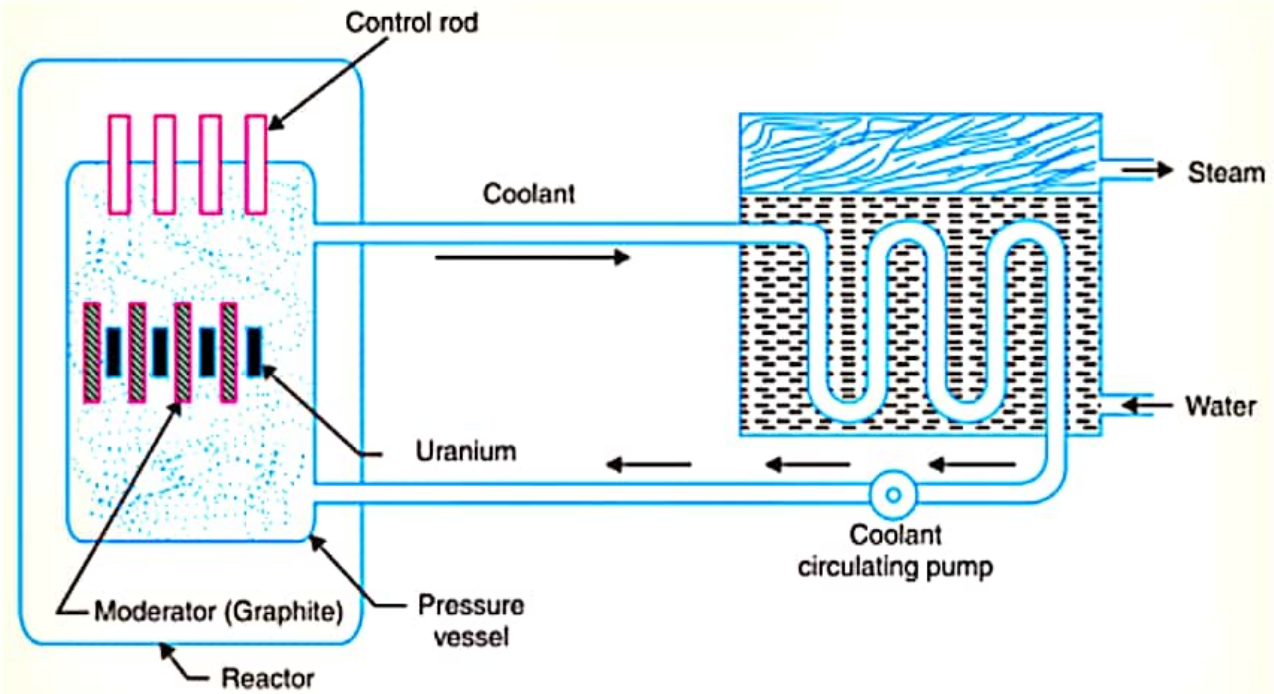
1. **Explain working of nuclear power plant with block diagram?**
2. **Draw the schematic arrangement of the typical nuclear power plant and state the function of reflector?**

The above figure shows, the schematic arrangement of nuclear power plant. Every nuclear power plant consists of following main parts, which are mentioned below:

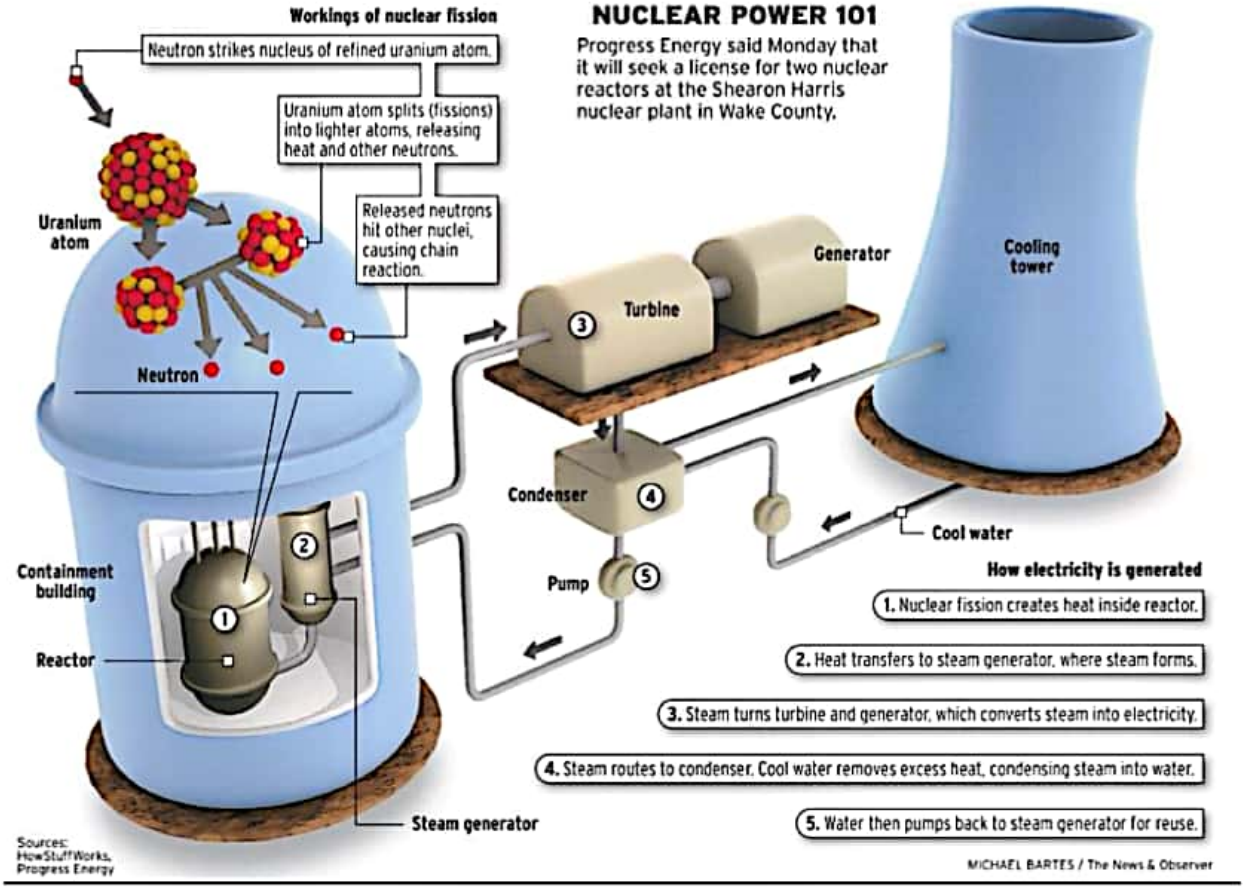
1. Nuclear Reactor
2. Heat Exchanger
3. Steam Turbine
4. Condenser & Cooling Tower
5. Feed Water Heater

The nuclear reactor function is to produce heat at high temperature. For producing heat the reactor uses, nuclear fuel these are uranium or thorium etc. when the slowly moving neutrons hits the nuclear fuel it produces heat. This heat passes to the heat exchanger; other input to this heat exchanger is heated water. The water is heated with the help of feed water heater. The main function of heat exchanger is to produce steam at high pressure. This high pressure steam passes to the steam turbine. When this steam flow towards turbine it starts rotating, the turbine & alternator are coupled mechanically. Simultaneously alternator starts rotating and the electrical power produced. The exhaust hot steam is passes to the condenser, where it is condensed by using cooling tower, and it is again passing to the heat exchanger through feed water heater. This process is continued.

MAIN PARTS OF REACTORS AND THEIR FUNCTION:



Nuclear Reactor



1. Fuel rods
Hundreds of 12-foot uranium rods undergo a fission reaction, releasing substantial heat.

2. Reactor
A steel pressure vessel contains the uranium rods, surrounding water and other reactor components.

3. Control rods
Operators can speed up or slow down the fission reaction by raising and lowering neutron-absorbing rods between the fuel rods.

4. Pump
A water pump keeps water circulating, which transfers heat away from the reactor core.

5. Pressuriser
The pressuriser contains water, air, and steam. By adding or releasing air in the pressuriser, operators can control the pressure of the coolant water around the reactor.

6. Heat exchanger
A pipe carries hot water from the reactor to a separate reservoir of water.

7. Steam generator
The hot pipe leading from the reactor heats a separate reservoir of water to the boiling point, generating steam.

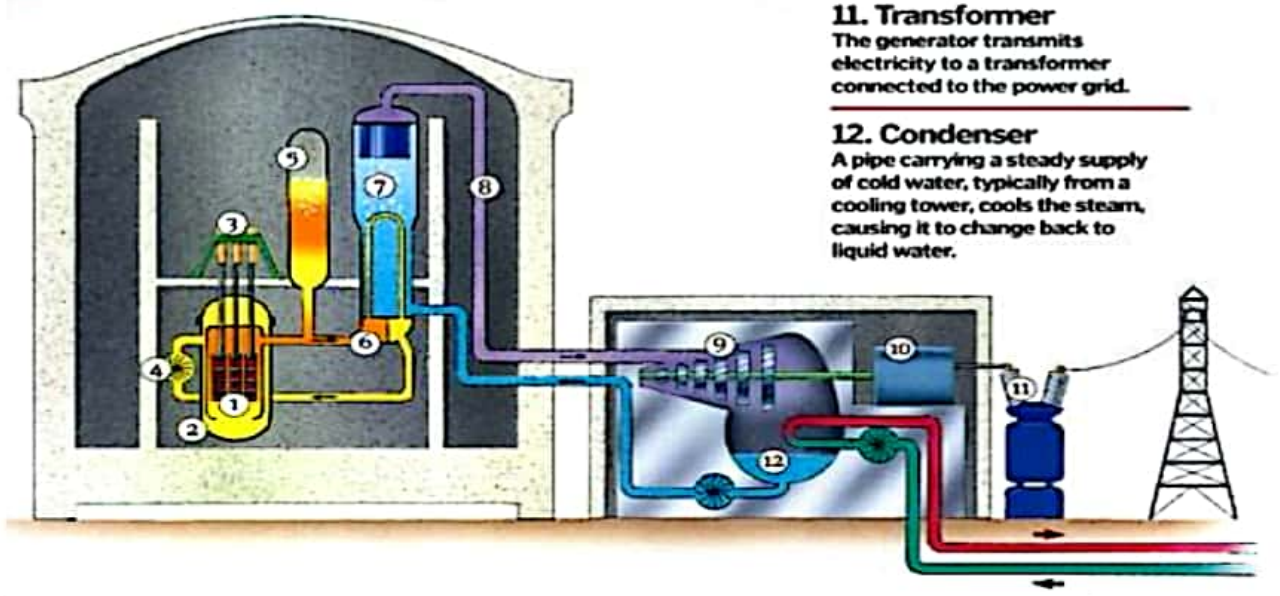
8. Steam line
Steam travels from the steam generator to the turbine.

9. Turbine
Rushing steam spins the turbine.

10. Generator
The turbine spins a rotor that sits in a magnetic field in a generator, inducing an electric current.

11. Transformer
The generator transmits electricity to a transformer connected to the power grid.

12. Condenser
A pipe carrying a steady supply of cold water, typically from a cooling tower, cools the steam, causing it to change back to liquid water.



MAIN PARTS & ITS EXPLANATION OF NUCLEAR REACTOR:

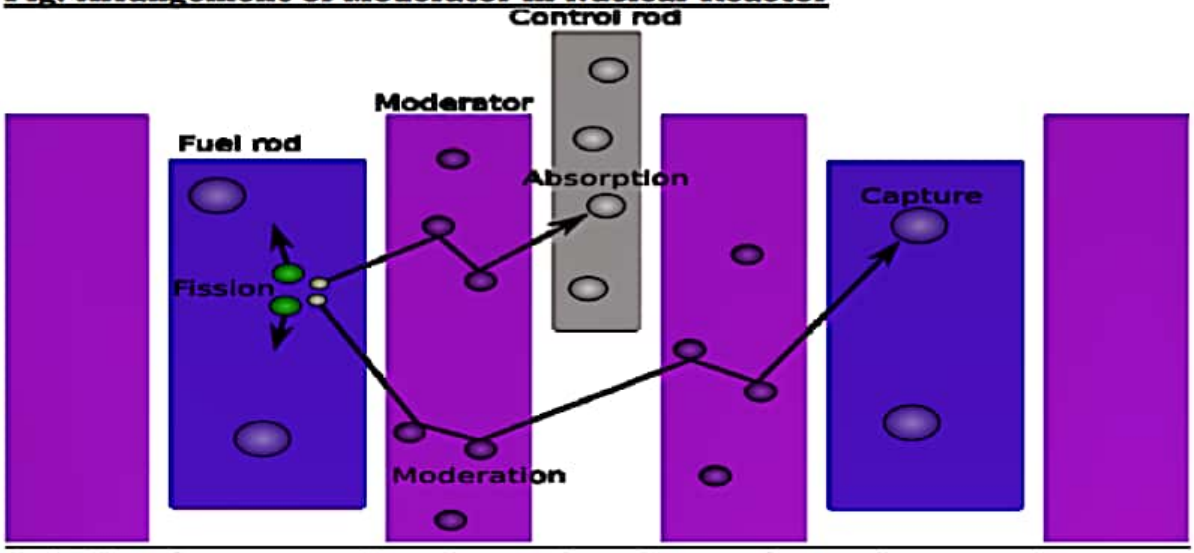
1. Nuclear Fuels.
2. Moderator.
3. Control rods.
4. Reflectors
5. Shielding
6. Reactor vessel
7. Heat Exchanger
8. Coolant
9. Turbine, 10. Condenser, 11. Cooling Tower,12. Water Treatment Chamber.

1. Nuclear Fuel:

In Nuclear Power Plant the fuels used are, or or . Out of the three fuel any one of the fuel used in nuclear power plant. The fuel is required in nuclear power plant to produce a huge amount of heat energy. The fuel are inserted in fuel rod, these fuel rods are bombarded with slow moving neutrons. Separate provision provided for bombarded or hits the neutron to the fuel rod, this device is known as neutron bombardment device.

2. Moderator:

Fig: Arrangement of Moderator in Nuclear Reactor



Q.1) Give four properties of a good moderator for nuclear reaction control?

In nuclear power plant, moderator is a device, of rod shaped. Moderator is placed near the nuclear fuel rod. The main function of moderator in nuclear power plant is reduce the speed of neutrons *(neutron at slower speed is required to produce fission)* & increases the fission processes. Moderator rod is made up of graphite or heavy water or beryllium material.

3. Control Rods:

In nuclear power plant, the control rods are placed in between nuclear fuel rod, moderator and then control rod. These control rods are operated either automatically or manually.(To start or stop the chain reaction). In nuclear power plant the main function of control rod is to control the chain reaction. If the control rod is inserted then it absorbs the freely moving neutrons & stop the chain reaction, if it is no inserted chain reaction is in process, means chain reaction continued. The steady rate or to stop the chain reaction is maintained through control rods. The control rods are made up of cadmium, boron (alloyed with steel or aluminium).

Q.1) Explain the purpose of shielding & reflector in nuclear power plant?
Q.2) State the purpose of reflector in nuclear power plant?

4. Reflector:

Before shielding, the reflector is placed. The reflector is used to surround the reactor core. The reflector will also help to bounce the escaping neutrons back to the reactor core & it conserve the nuclear fuel.

5. Shielding:

Shielding is the also important part of nuclear power plant, shielding is in other words protecting. In nuclear reactor, first one is nuclear fuel rod then moderator, control rod & reflector. Through this shielding is provided. When the chain reaction starts, heat energy start to produce. During this period lots of radiation or rays are produced, these are very harmful; to avoid this shielding is provided in reactor.

6. Reactor vessel:

After shielding the next layer is a reactor vessel. This vessel encloses reactor core, reflector, shielding. It is used to protect complete nuclear reactor. Few holes are provided in the top portion of reactor vessel to insert control rods & at lower side of this vessel fuel & moderator assembly are placed.

7. Heat Exchanger:

The main function of heat exchanger in nuclear power plant is the boiled the cold water and produces steam at high temperature & pressure.
Heat exchanger is used in nuclear power plant, to exchange the heat i.e. it consists of one input to feed the cold water & output to flow of hot steam. The heat exchanger receives the heat from reactor, this heat is continuously circulated through pipe, before it is re-entered to the reactor it is filter. By using this heat a heat exchanger boils the cold water produces steam at high temperature & Pressure. Further this steam passes to the steam turbine for generation of electrical power.

8. Coolant:

Q.1) Write the function of coolant in nuclear power plant?

The coolant becomes a cold metal. In coolant the gases are used like carbon dioxide, air, hydrogen etc. the heats from the heat exchanger are re-circulated to the reactor through pump after filtration. During filtrations the unwanted impurities in the coolant are removed.

9. Turbine:

We know that, the turbine is a mechanical device and it is mechanically coupled with alternator. In case of nuclear power plant turbine receives steam from heat exchange at high pressure, and it rotates at high speed then alternator also rotates, this way electrical power produced. The exhaust steam from turbine passes to condenser for further use.

10. Condenser:

The condenser receives an exhaust hot steam from turbine; with the help of water it is cooled. Water taken from available water sources e.g. river and is filtered in water treatment plant. This water is re-circulated to heat exchanger through feed water heater & Pump.

11. Cooling Tower:

The cooling towers are used to convert the hot water or steam exhausted from turbine into normal water. That is, its temperature decreases at normal temperature.

12. Water treatment chamber:

The water treatment chamber provides filter water to the cooling tower, condenser through available water source. It also reduces unwanted impurities in the stored water.

Types of Nuclear Reactor:

The nuclear reactors are classified into four types. These are mentioned below:

1. Pressurised Water Reactor (PWR).
2. Boiling Water Reactor (BWR).
3. Advanced Gas Cooled Reactor (AGCR).
4. Fast Breeder Reactor (FBR).

1. Pressurised Water Reactor (PWR).

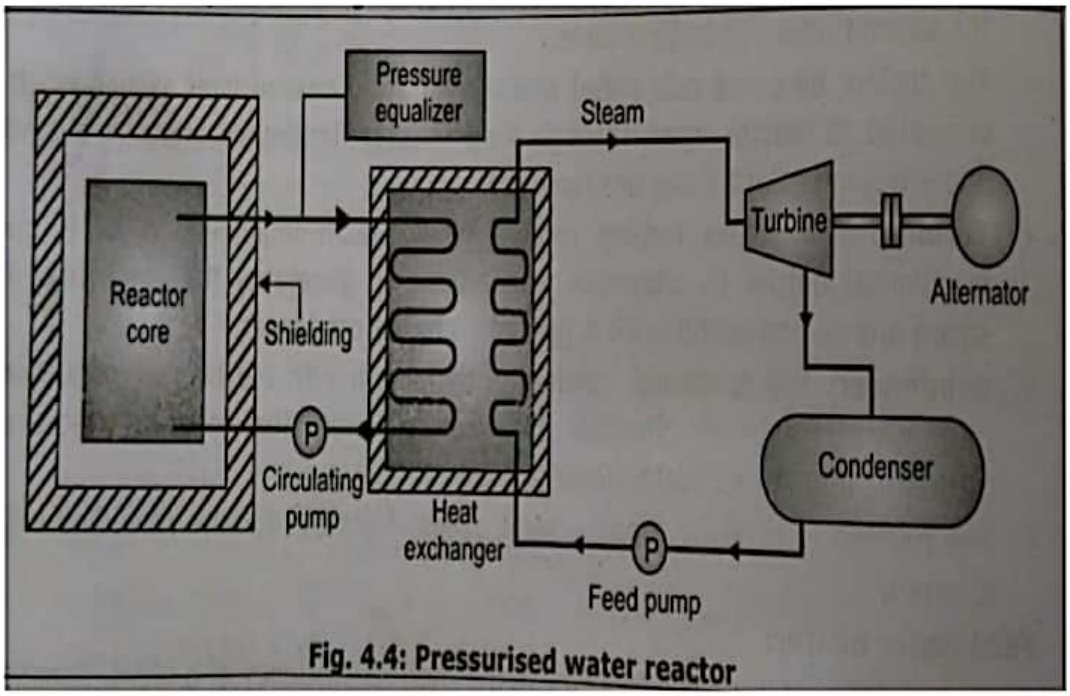
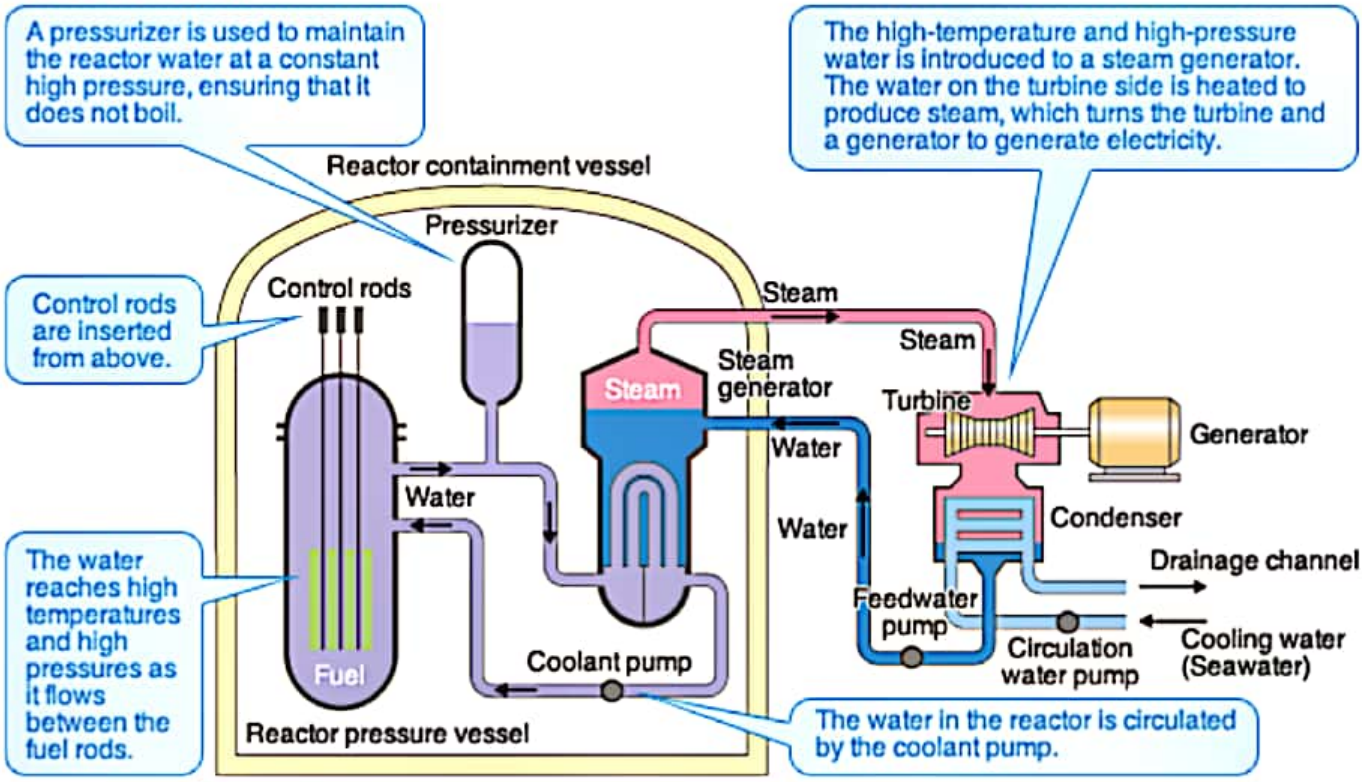


Fig. 4.4: Pressurised water reactor

Pressurized water reactor (PWR)

The interior of the reactor is maintained at a high pressure to prevent water from boiling despite its high temperature; a steam generator produces steam using water other than the water flowing inside the reactor.



Q.1) Explain working of pressurised water nuclear reactor?

Ans- In PWR the enriched uranium fuel is used. When the chain reaction starts the reactor core produces heat energy at high temperature. This produced heat energy passes to the heat exchanger. We have passed the hot metal to the heat exchanger, this metal is also radioactive, and that's why heat exchanger also requires shielding. The pressure equalizer uses to maintain the pressure of hot metal. In heat exchanger, other side tubes of water are inserted; this will help us to boil the water & Produces steam at high pressure. This steam passes to the steam turbine for the generation of electrical energy with the help of alternator. After that the exhausted steam passes to the condenser this process is continued.

2. <u>Boiling Water Reactor (BWR)</u>

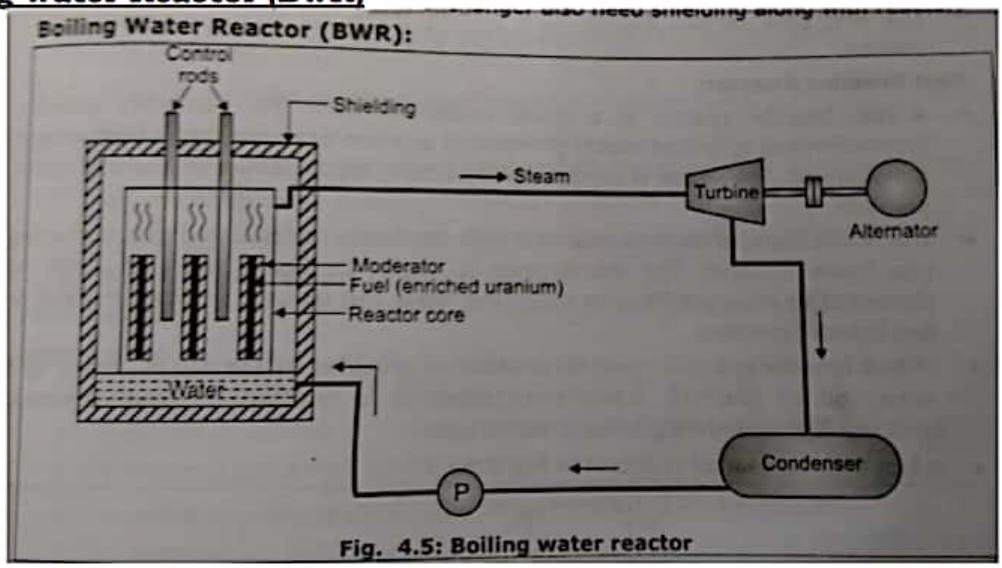
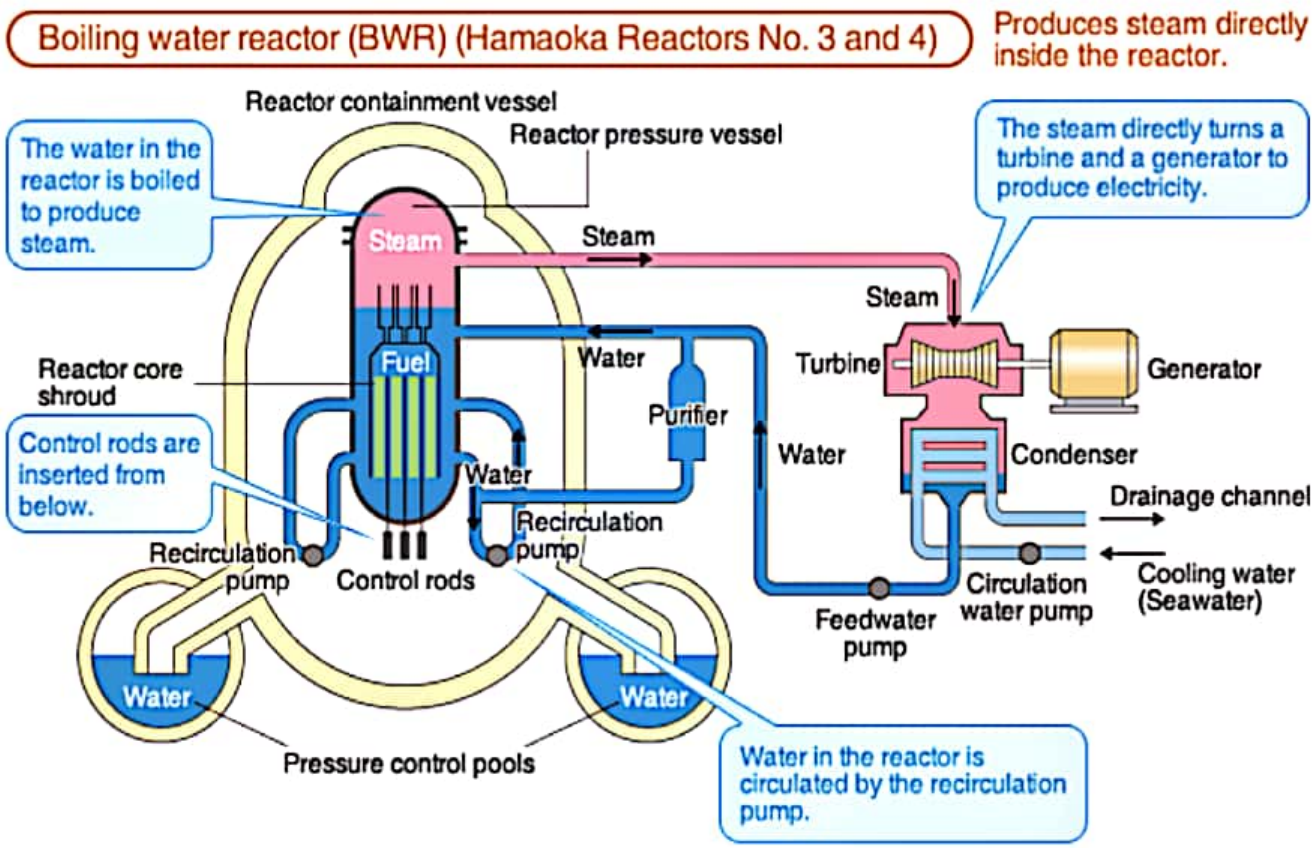


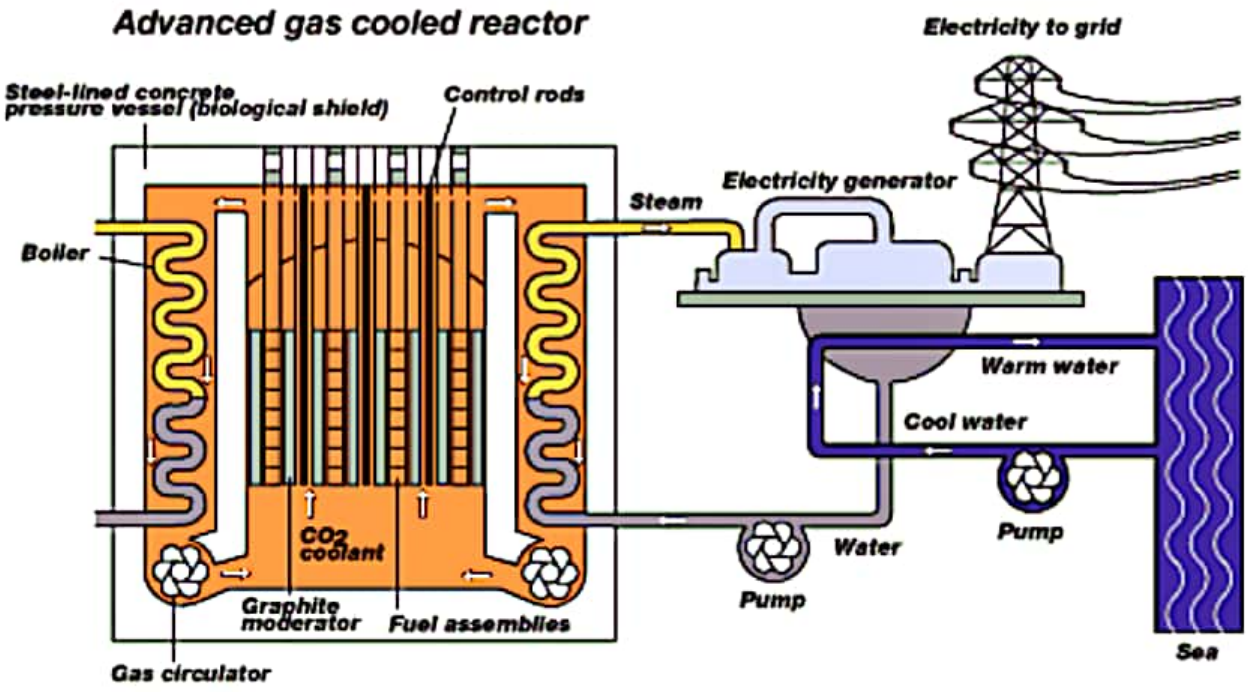
Fig. 4.5: Boiling water reactor



Q.1) Explain working of boiler water nuclear reactor?

Ans- In BWR, the enriched uranium fuel is used in reactor. In this type of reactor water is directly passes to the bottom of reactor core. When the chain reaction starts, the reactor core produces a heat energy, which is help full to boiled the water & produced steam at high temperature & Pressure. This steam passes to the turbine, through turbine-alternator combination electrical power produced. The exhausted steam from the steam turbine passes to the condenser. Where it is condensed, and again passes to the reactor core through pump.

3. Advanced Gas Cooled Reactor



Q.1) With a neat diagram, explain the main features of advanced gas cooled reactor?

Ans- As its name indicates, it is advanced for the PWR & BWR. For the above mentioned two reactors, we used water for the production of steam. But in case of advanced gas cooled reactor gas is used. This gas is passes to the heat exchanger, the heat exchanger receives heat from reactor core, where its temperature increases, and then it runs the turbine in this way electrical power is produced.

A gas is of inferior quality to water so far as heat transfer properties are concerned, because of its poor heat transfer qualities; it required large quantity of gas for circulation. In advanced gas cooled reactor either carbon dioxide or helium is used as a coolant.

4. Fast Breeder Reactor:

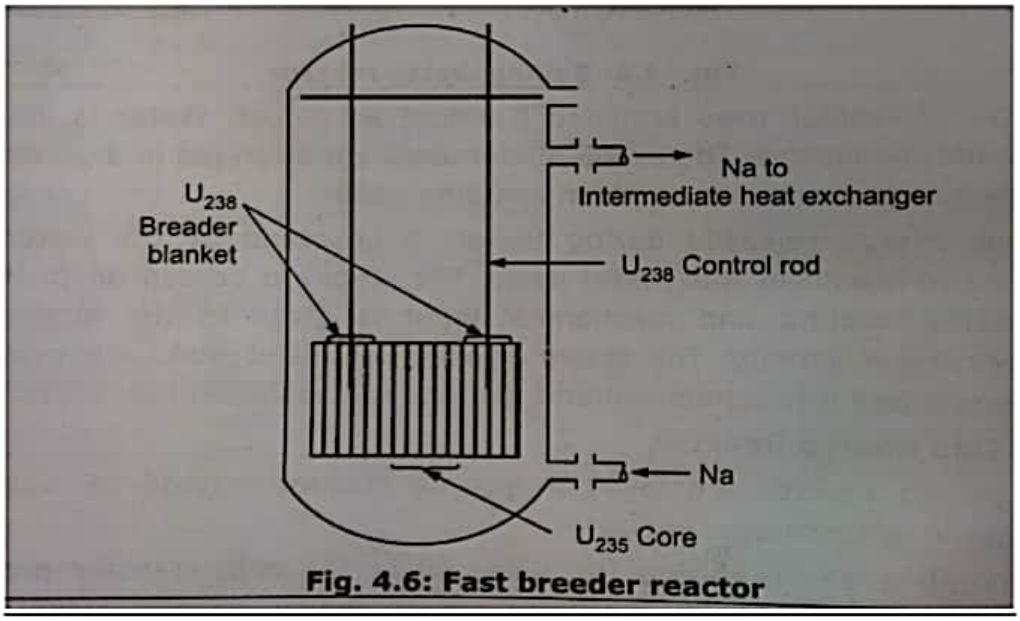


Fig. 4.6: Fast breeder reactor

In fast breeder reactor the fuel used are either enriched uranium or plutonium. Without using moderator the fuels are kept in fuel blanket. The closed vessel is surrounded by a fairly thick blanket. The shielding is also provided with boron material. The core of reactor is cooled by liquid metal.

CONTROL OF NUCLEAR REACTOR:

Q.1) How are nuclear reactor controlled? Explain two different methods in brief?

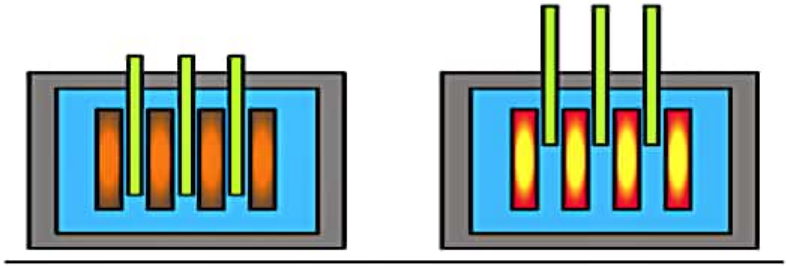
As we already studied that, why the control rods are used in the nuclear reactor?

In this point we have to study how the nuclear reactors are controlled.

The nuclear reactors are controlled in two ways:

1. By using control rods.
2. Control through flow of coolant.

1. By using control rods:



Q.1) Explain how nuclear reactor is controller using control rods?
Q.2) Explain the role of control rod in nuclear reactor. State any two materials for control rod.

We know that, in nuclear reactor uranium or thorium or plutonium materials are used for generation of heat energy. If a slowly moving neutron hits or bombarded with this heavy nucleus of nuclear fuel then the chain reaction starts. Once the chain reaction starts then it is continued. By using control rods, we have to maintain its rate of flow of neutron or its speed, if the control rod is not used in the nuclear reactor this process is very dangerous to control. In other words this process is works like atomic bomb. To avoid this control rods are used in nuclear reactor. The main function of control rod in nuclear reactor is to absorb the freely moving neutrons. To absorb these freely moving neutrons from nuclear reactor the control rods are made up of either boron or cadmium. The diameter of control rod is 8cm. its height is just more than nuclear reactor. The control rods operated either automatically or manually. If it is operated automatically then sensors are used, these sensors give signals to the control rods. The rods are operated in up & down direction, if it in up then more heat generated & if it is down then it control the reaction i.e. rate of heat generated is minimum.

2. Control through flow of coolant:

We know that, the heat is generated in nuclear reactor. This heat is passes to the heat exchanger for the conversion of boiled water into steam. So the coolant is used in the nuclear reactor to remove the heat generated. As the operating temperature of nuclear reactor fluid coolant is used of higher thermal conductivity. There are different methods of nuclear reactor cooling:

1. Annular ducts surrounding and coolant is passed is passed through them.
2. Completely immerse the reactor fuel element in coolant bath.
3. A fluid mixture of fuel & moderator is circulated through the reactor.

Nuclear Waste Management:

Q.1) Explain how nuclear waste is disposed?
Q.2) State the types of radioactive waste generated in a nuclear power station. Explain the method employed for their disposal?
Q.3) how will you dispose nuclear waste? Explain the method for solid, liquid & gaseous waste?

In Second World War, we know that the real condition of Japanese city like Hiroshima & Nagasaki. For consider this example, you know the idea of the: radioactivity material or how it is dangerous. The same material we have to use in nuclear reactor, every part of nuclear fuel cycle produces radioactive waste. These wastes are very dangerous to human health & it handling very carefully. For e.g. how much electricity generated through nuclear power plant out of that 5% is cost of wastage. Based on this means the level of radioactivity material or radiations, nuclear waste management is classified into three types:
Classification of nuclear (Radioactive) Wastage:

1. Low Level Waste (LLW)
2. Intermediate Level Waste (ILW)
3. High Level Wastage (HLW)

1. LLW (Low Level Waste):

In case of low level waste, the (% Content of Radioactivity) radioactive level is very less. Normally, this type of waste comes from industries, hospitals, small nuclear plant. At the time of handling & transport the low level waste, it does not require shielding. The low level waste buried in land with suitable depth at the time of disposal.

2. ILW (Intermediate Level Waste):

The percentage of radioactivity is higher as compared with low level waste. At the time of handling & transportation shielding is required because, the produce radioactive are very difficult. It means that it's affected to human health. At the time of ILW disposal first up all it is placed in concrete container, after that it is well sealed. Finally the ILW is buried in underground facility.

3. HLW (High Level Waste):

As compared with LLW & ILW, the HLW is very dangerous to handling as well as it is directly affected to human health. Most of accidents in nuclear power plants are occurred due to this HLW. At the time of handling it requires shielding as well as cooling. The HLW mainly comes from reprocessing of nuclear fuel in the reactor. The HLW is obtained in liquid form & the heat % is very high. There are three ways to dispose the HLW.

i. With the help of Storage Tank:

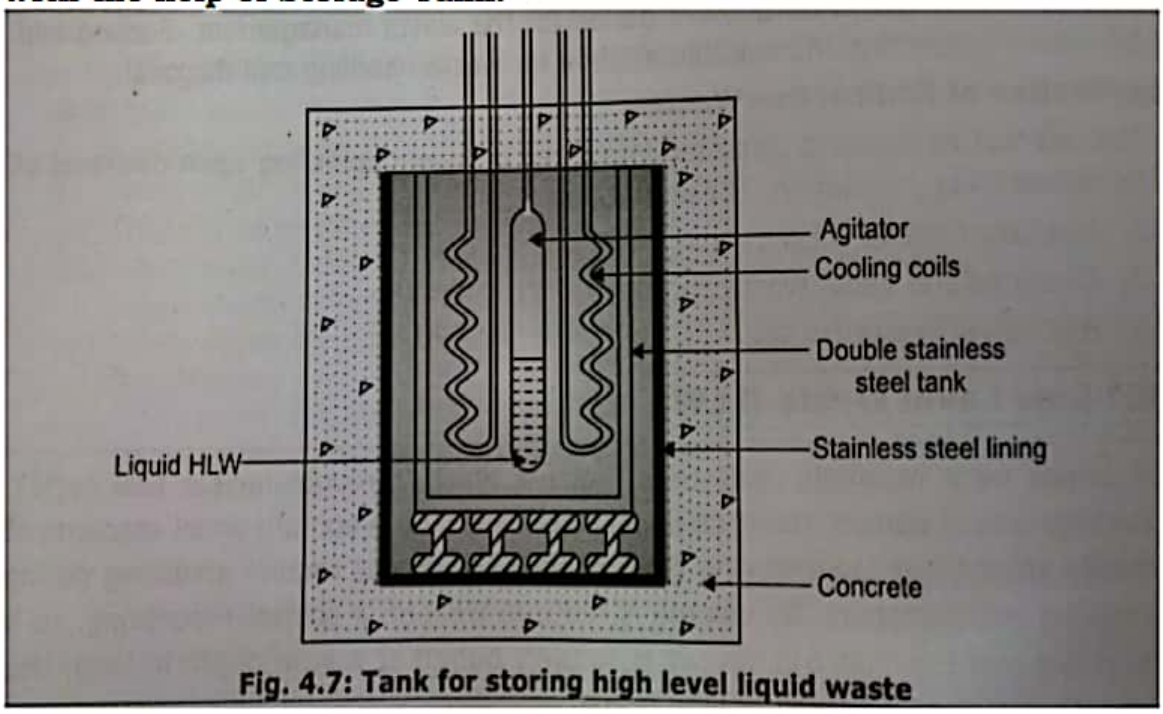


Fig. 4.7: Tank for storing high level liquid waste

The agitator is placed, which is rotating type. In that agitator the high temperature liquid waste is kept. Due to its continuous rotation, & outer cooling, it will help to its high temperature is converter into its normal value. For the protection & leak proof purpose the closed vessel surrounded by stainless steel tank & concrete layer. Whenever the tank is full, it will be well sealed & buried underground.

ii. Disposal through Deep Well Injection:

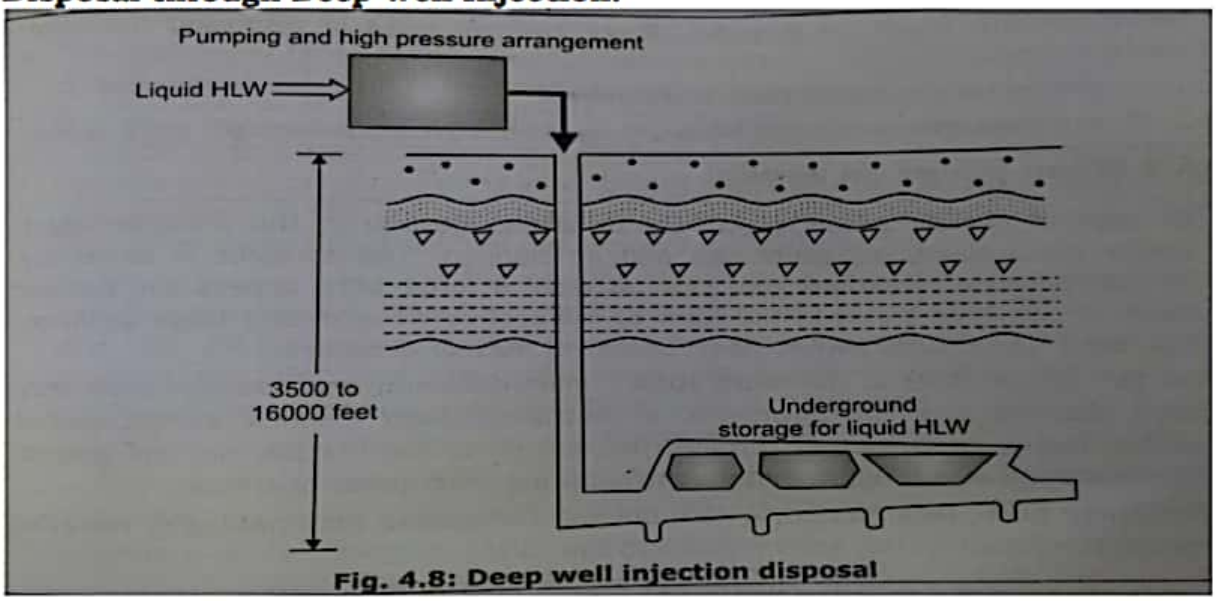


Fig. 4.8: Deep well injection disposal

In this method, first up all the high temperature liquid HLW is kept in storage tank. Then with the help of pumps these liquid HLW is sent to ground at high pressure. Its depth is normally 3500 to 16000 feet.

iii. Vitrification Process:

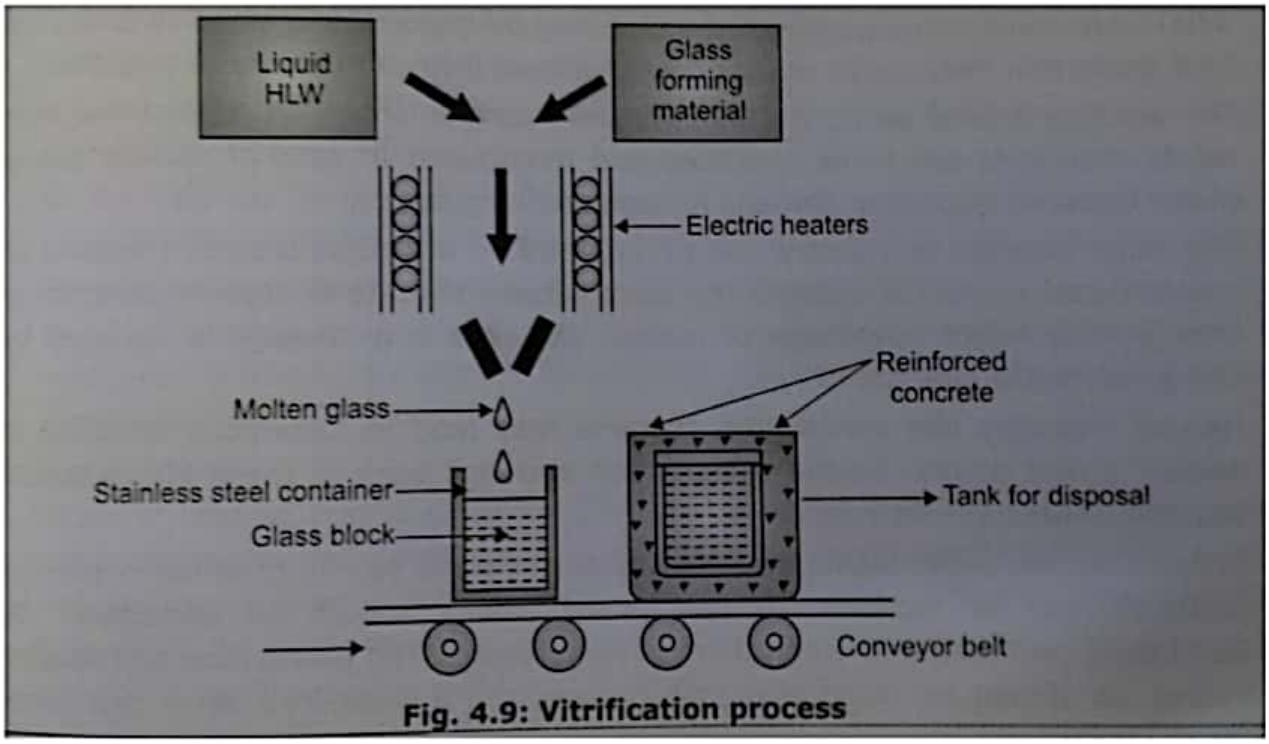


Fig. 4.9: Vitrification process

We know that, the HLW is liquid form & it is difficult to handling and disposal. To overcome this drawback in vitrification process first up all it is converted into solid form (the liquid form of HLW is converted into solid form is known as vitrification). Whenever the liquid HLW is kept with steel container, it is mixed with glass forming material through heating process. Due to this a solid glass is formed which is put in steel container, after that it is surrounded by reinforced concrete. These tanks are now ready for disposal.

There are two ways of disposing these solid waste tanks:

1. It can be kept in trench deep underground.
2. It can be suspended in sea beads.

Advantages of Nuclear Power Station:

1. A nuclear power station occupies much smaller space compared to other conventional power station of same capacity.
2. This station does not require plenty of water; hence it is not essential to construct plant near natural source of water.
3. This also does not required huge quantity of fuel; for e.g. 1 kg of uranium produces a heat which is equivalent to 4300 tonnes of coal.
4. It is possible to locate the plant near to load center
5. If bulk power is produced it is economical.
6. Clean operation, no ash is produced.
7. Area required is very less.
8. Independent of geographical conditions.
9. Saving of natural resources such as coal, oil, gas etc.

Disadvantages of Nuclear Power Plant

1. The fuel is not easily available and it is very costly.
2. Initial cost for constructing nuclear power station is quite high.
3. Erection and commissioning of this plant is much complicated.
4. The fission by products is radioactive in nature, and it may cause high radioactive pollution.
5. The maintenance cost is higher and the man power required to run a nuclear power plant is quite higher since specialty trained people are required.
6. Sudden fluctuation of load cannot be met up efficiently by nuclear plant.
7. It is very big problem for disposal of this by products. It can only be disposed deep inside ground or in a sea away from sea share.
8. Enrichment technology is essential for fuel processing & fabrication.
9. Maintenance cost is very high.
10. Waste disposal is problematic.
11. For variable load it is not suitable.
12. Construction is complicated.

QUESTION FOR PRACTICE

1. Write down the advantages and disadvantages of Nuclear Power Plant.
2. Discuss about the type of Nuclear Wastes & What are the processes for the disposal of such Wastes? Explain.
3. With a neat sketches Describe the working procedure of PWR & BWR?
4. What are the components of a Nuclear Power Plant? Explain each one of them.
5. What do you mean by Nuclear Fission & Nuclear Fusion reactions?
6. Explain the working of a Nuclear Power Plant with Block diagram?
7. What are the governing conditions for setting up of a Nuclear Power Plant?