UNIT-4

1.What is meant by Nuclear Fission, Nuclear Fusion, Nuclear Fuels used in Nuclear Reactors

Ans: Nuclear Fission

Nuclear fission is the reaction by which a heavy nucleus (that is one with a high value of Z) is hit with a small particle, as a result of which it splits into two (occasionally more) smaller nuclei.

Nuclear Fusion

Fusion is the opposite of fission, it is the joining together of two light nuclei to form a heavier one (plus a small fragment). For example if two 2H nuclei (two deuterons) can be made to come together they can form He and a neutron.

Nuclear Fuel:

Fuel of a nuclear reactor should be fissionable material which can be defined as an element or isotope whose nuclei can be caused to undergo nuclear fission by nuclear bombardment and to produce a fission chain reaction. It can be one or all of the following U233, U235 and Pu239.

Natural uranium found in earth crust contains three isotopes namely U234, U235 and U238 and their average percentage is as follows : U238 — 99.3% U235 — 0.7% U234 — Trace Out of these U235 is most unstable and is capable of sustaining chain reaction and has been given the name as primary fuel.

U233 arid Pu239 are artificially produced from Th232 and U238 respectively and are called secondary fuel.

Pu239 and U233 so produced can be fissioned by thermal neutrons. Nuclear fuel should not be expensive to fabricate. It should be able to operate at high temperatures and should be resistant to radiation damage.

2. What is the use of Cladding and its Properties

Ans: The **purpose of cladding** is to protect a building's structure from natural elements like wind and rain but it can have other benefits, such as, insulation, noise control .
Aluminum, stainless steel, and zirconium alloys are common **cladding** materials

Fuel element cladding should possess the following properties :

1. It should be able to withstand high temperature within the reactor.
2. It should have high corrosion resistance.
3. It should have high thermal conductivity.
4. It should not have a tendency to absorb neutrons.
5. It should have sufficient strength to withstand the effect of radiations to which it is subjected.

Uranium oxide (UO2) is another important fuel element. Uranium oxide has the following advantages over natural uranium:

1. It is more stable than natural uranium.
2. There is no problem or phase change in case of uranium oxide and therefore it can be used for higher temperatures.

3. It does not corrode as easily as natural uranium.
4. It is more compatible with most of the coolants and is not attacked by H2, N2.
5. There is greater dimensional stability during use.

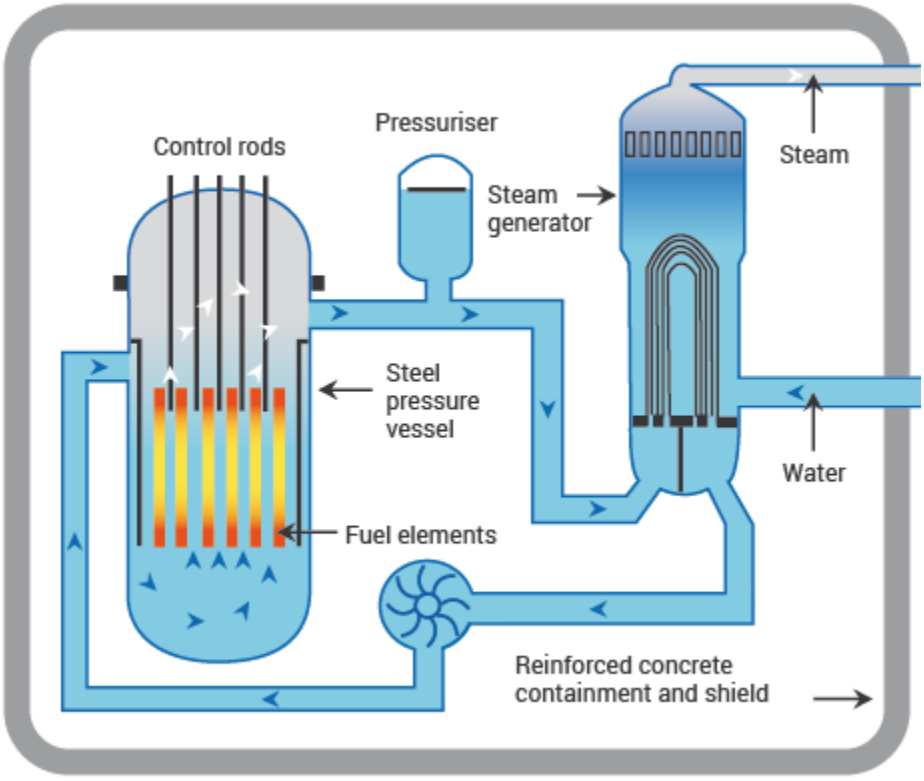
Uranium oxide possesses following disadvantages:
1. It has low thermal conductivity.
2. It is more brittle than natural uranium and therefore it can break due to thermal stresses.
3. Its enrichment is essential.

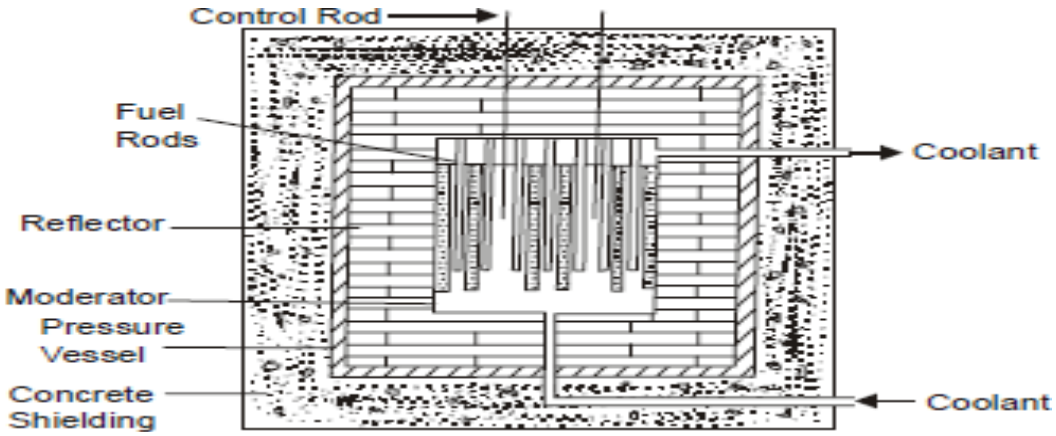
Uranium oxide is a brittle ceramic produced as a powder and then sintered to form fuel pellets. Another fuel used in the nuclear reactor is uranium carbide (UC). It is a black ceramic used in the form of pellets.

3. Explain the Working Principle of Nuclear Reactor, Advantages and Disadvantages

NUCLEAR REACTOR:

A nuclear reactor is an apparatus in which heat is produced due to nuclear fission chain reaction. The fig shows the various parts of reactor, which are as follows:
1. Nuclear Fuel
2. Moderator
3. Control Rods
4. Reflector
5. Reactors Vessel 6. Biological Shielding 7. Coolant





Nuclear Reactor

It is an apparatus in which heat is produced due nuclear fission chain reaction for the generation of electricity

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Principle:

It works on the **principle** of achieving controlled chain reaction of Uranium 238U enriched with 235U and as a result generating huge amount of energy. The controlled chain is made possible by inserting rods that can absorb neutrons (control rods) and use them to maintain the reaction rate.

Inside the **reactor** vessel, the fuel rods are immersed in water which acts as both a coolant and moderator. The heat created by **fission** turns the water into steam, which spins a turbine to produce carbon-free electricity.

. Main Components

1. Reactor Core

It consists of fuel elements, control rods, coolant, moderator and pressure vessels. Cores generally have shapes of right circular cylinders with diameters ranging from .5 to 15 metres.

Fuel rods made of uranium rods clod in thin sheath of stainless steel, zirconium or aluminium.

2. Reflector- It is placed round the core, to reflect back some of the neutrons that leak out from core surface.

It is made up of heavy mass element. it simply absorbs the neutrons so that it can either maintain or stop a reaction. Examples-Cadmium,lead

3. Control Rods-It has following purposes- 1. For starting the reactor. 2.For maintaining at that level. 3. For shutting the reactor down under normal or emergency conditions.

Hence the rate of reaction achieves a finite constant value. When rate of reaction achieves a permissible value then control rods are inserted between the fuel rods in such a way that K becomes equal to 1.

4 Moderator function: The number of neutrons keeps on decreasing, i.e., rate of reaction decreases,

hence the reaction stops after a certain interval of time. To shut down the reactor either in normal or emergency conditions, the control rods are inserted in such a way that K becomes less than 1. υFor shutting down the reactor

Main moderator used: 1. Water H2O. 2. Heavy water D2O. 3. Graphite. 4. Beryllium.

Function: To slow down neutrons from high velocities and hence high energy level which they have on being released from fission process so that probability of neutron to hit the fuel rods increases.

Characteristics 1. Low Melting point 2. high Boiling point 3. chemical and radiation stability 4. Low viscosity 5. Non toxicity 6. Non corrosiveness

5. Function Coolant is used to remove intense heat from the produced in the reactor and that heat can be transferred to water in a separate vessel which is converted into steam and runs the turbine.

Commonly used Coolants

1. Hg 2. He 3. CO2 4. H2O Mostly used gaseous Coolant is CO2

6 Shielding is required to protect the working men from the harmful effects of the radiation.

ADVANTAGES OF NUCLEAR POWER PLANT

The various advantages of a nuclear power plant are as follows:

1. Space requirement of a nuclear power plant is less as compared to other conventional power plants are of equal size.

2. A nuclear power plant consumes very small quantity of fuel. Thus fuel transportation cost is less and large fuel storage facilities are not needed Further the nuclear power plants will conserve the fossil fuels (coal, oil, gas etc.) for other energy need.

3. There is increased reliability of operation.

4. Nuclear power plants are not effected by adverse weather conditions.

5. Nuclear power plants are well suited to meet large power demands. They give better performance at higher load factors (80 to 90%).

6. Materials expenditure on metal structures, piping, storage mechanisms are much lower for a nuclear power plant than a coal burning power plant.

DISADVANTAGES

1. 1. Initial cost of nuclear power plant is higher as compared to hydro or steam power plant.
2. 2. Nuclear power plants are not well suited for varying load conditions.
3. 3. Radioactive wastes if not disposed carefully may have bad effect on the health of workers and other population.

4. Maintenance cost of the plant is high.

5. It requires trained personnel to handle nuclear power plants.

TYPES OF REACTORS:

PRESSURISED WATER REACTOR
BOILING WATER REACTOR
SODIUM-GRAPHITE REACTOR
FAST BREEDER REACTOR
HOMOGENEOUS REACTOR
GAS COOLED REACTOR

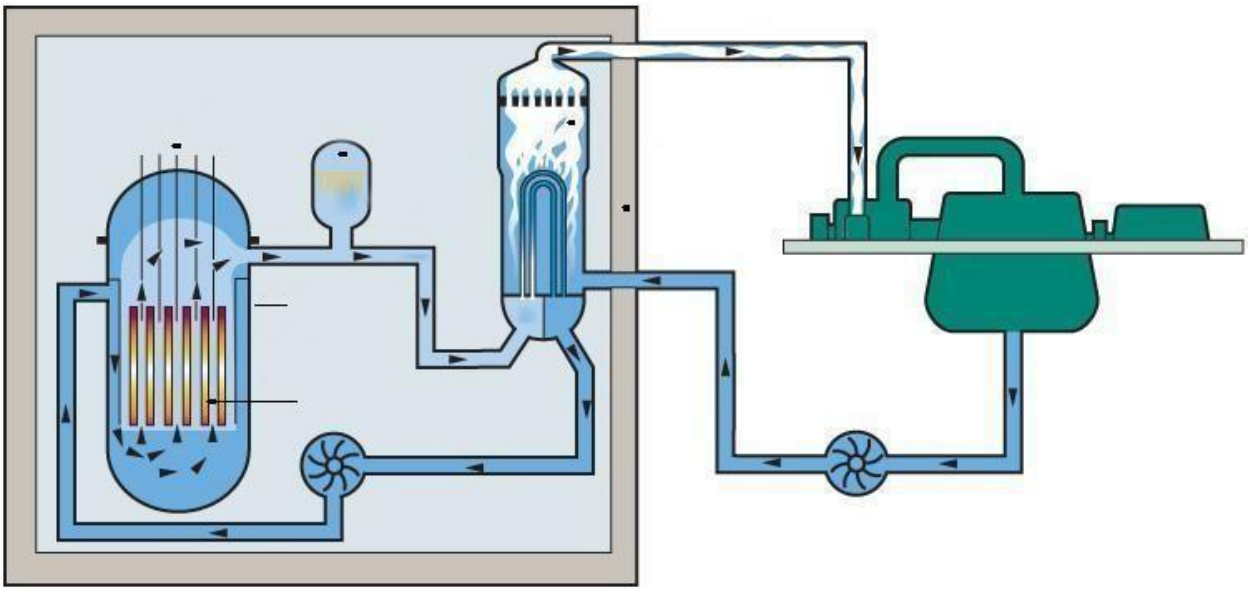
4 Explain Pressurized Water Reactor Advantages and Disadvantages:

Ans: The core inside the **reactor** vessel creates heat. **Pressurized water** in the primary coolant loop carries the heat to the steam generator. The steamline directs the steam to the main turbine, causing it to turn the turbine generator, which produces electricity

The most widely used reactor type in the world is the Pressurised 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.

The high-pressure water is then passed through a steam generator, which raises steam in the usual way.



PRESSURISED WATER REACTOR:

Advantages

[1] One major advantage of this reactor is that it is easy to operate because less power is being produced as the heat increases.

[2] In addition, the core of the reactor contains less fissile material, decreasing the chances of additional fission events to occur, making the reactor safer and more controllable.

[3] In other words, it contains "less fissile material than is required for them to go prompt critical".

[4] Lastly, the most advantageous element of the PWR is the turbine cycle. Since the primary and secondary loops are separate,

[5] water can never be contaminated by radioactive material in the main system loop. Conclusively, the water from the primary and secondary loops will never touch or mix, so there is no chance for contamination.

Disadvantages

Although the PWR makes up the majority of Western Nuclear plants and is the reactor choice for most Navy Nuclear Propulsion Systems, there are some notable disadvantages to using such a reactor.

[1] For one thing, the reactor requires very strong piping and a heavy pressure vessel in order to ensure that the highly pressurized water remains at a liquid state when sustaining high temperatures, making the construction of the PWR costly.

[2] Meanwhile, most reactors need to be refueled after about 18 months, and cannot be refueled while the reactor is running. Since the refueling process takes a few weeks, the reactors must go offline for this time.

[3] Lastly, although no water contamination in the main cycle exists, boric acid, which is corrosive to carbon steel, can get melted into the coolant causing radioactive products to circulate throughout the loop.

[4] These radioactive yields are destructive to the reactor (i.e. potential for radiation exposure) ultimately limiting the reactor's operating life.

4 Explain Boiling Water Reactor Advantages and Disadvantages :

Ans: A **boiling water reactor** (BWR) is a type of light **water** nuclear **reactor** used for the generation of electrical power. 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. This, however, leads to some radioactive contamination of the steam circuit and turbine, which then requires shielding of these components in addition to that surrounding the reactor.

The steam in a pressurized water reactor is produced in a secondary system while the steam in boiling water reactor is produced directly in the reactor core. The pressure of a pressurized boiling reactor varies from the primary system to the output steam while the pressure of a boiling water reactor remains constant.

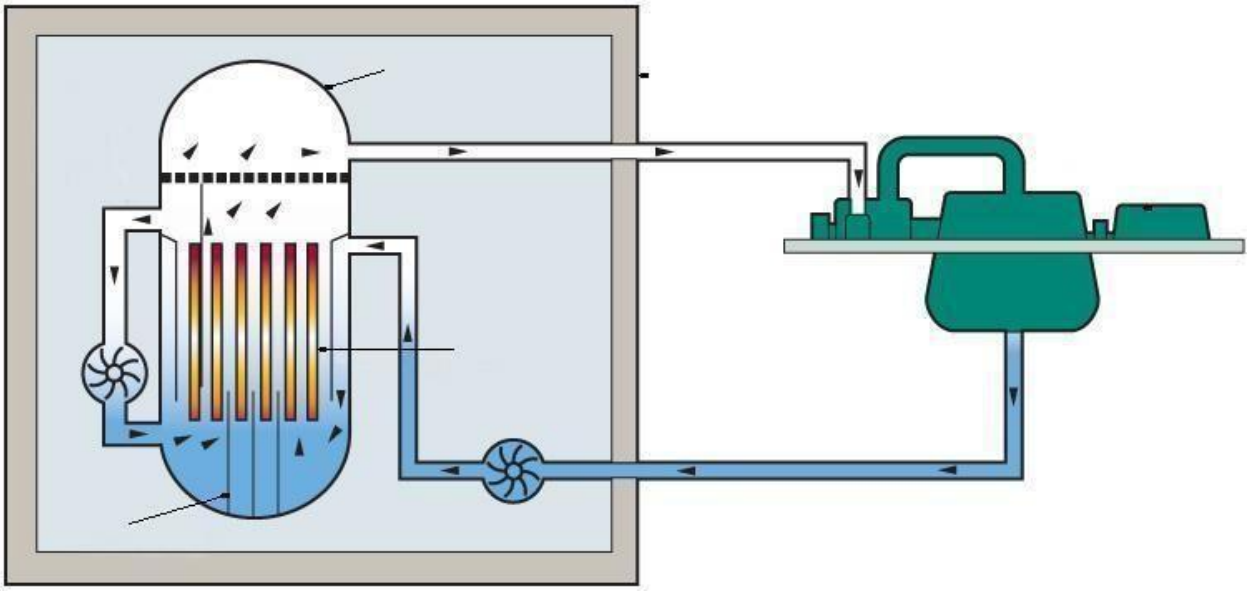
The main difference between a BWR and PWR is that in a BWR, the **reactor** core heats **water**, which turns to steam and then drives a steam turbine. In a PWR, the **reactor** core heats **water**, which does not **boil**.

Advantages

- The reactor vessel and associated components operate at a substantially lower pressure of about 70–75 bars (1,020–1,090 psi) compared to about 155 bars (2,250 psi) in a PWR.
- Pressure vessel is subject to significantly less irradiation compared to a PWR, and so does not become as brittle with age.
- Operates at a lower nuclear fuel temperature.
- Fewer components due to no steam generators and no pressurizer vessel. (Older BWRs have external recirculation loops, but even this piping is eliminated in modern BWRs, such as the ABWR.) This also makes BWRs simpler to operate.
- Lower risk (probability) of a rupture causing loss of coolant compared to a PWR, and lower risk of core damage should such a rupture occur. This is due to fewer pipes, fewer large diameter pipes, fewer welds and no steam generator tubes.

Disadvantages

- BWRs require more complex calculations for managing consumption of nuclear fuel during operation due to "two phase (water and steam) fluid flow" in the upper part of the core. This also requires more instrumentation in the reactor core.
- Larger pressure vessel than for a PWR of similar power, with correspondingly higher cost, in particular for older models that still use a main steam generator and associated piping.
- Contamination of the turbine by short-lived activation products. This means that shielding and access control around the steam turbine are required during normal operations due to the radiation levels arising from the steam entering directly from the reactor core. This is a moderately minor concern, as most of the radiation flux is due to Nitrogen-16 (activation of oxygen in the water), which has a half-life of 7 seconds, allowing the turbine chamber to be entered into within minutes of shutdown.



Boiling Water Reactor

5 Explain Fast Breeder Reactor Advantages and Disadvantages:

Ans: A **Fast Breeder Reactor** (FBR) is a nuclear **reactor** that uses **fast** neutron to generate more nuclear fuels than they consume while generating power, dramatically enhancing the efficiency of the use of resources. Nuclear fission by **fast** neutron causes the increase in neutrons generated.

A breeder reactor is a nuclear reactor that generates more fissile material than it consumes.

These devices achieve this because their neutron economy is high enough to breed more fissile fuel than they use from fertile material, such as uranium-238 or thorium-232.

Breeders were at first found attractive because their fuel economy was better than light water reactors

Advantages

- Fast Breeder Reactor – Nuclear **Power** Plant Reactor.
- Such reactors are designed to produce more fissile material (Plutonium) than they consume (**Thorium** Th-232). ...
- The fertile material (U-238 or Th-232) absorbs neutrons produced by the fissioning of U-235 and produces fissile material Pu-239 or U-233 respectively.

A breeder reactor creates 30% more fuel than it consumes. After an initial **introduction** of enriched uranium, the reactor only needs infrequent addition of stable uranium, which is then converted into the fuel.

It can generate much more **energy** than traditional coal **power** plants.

Disadvantages

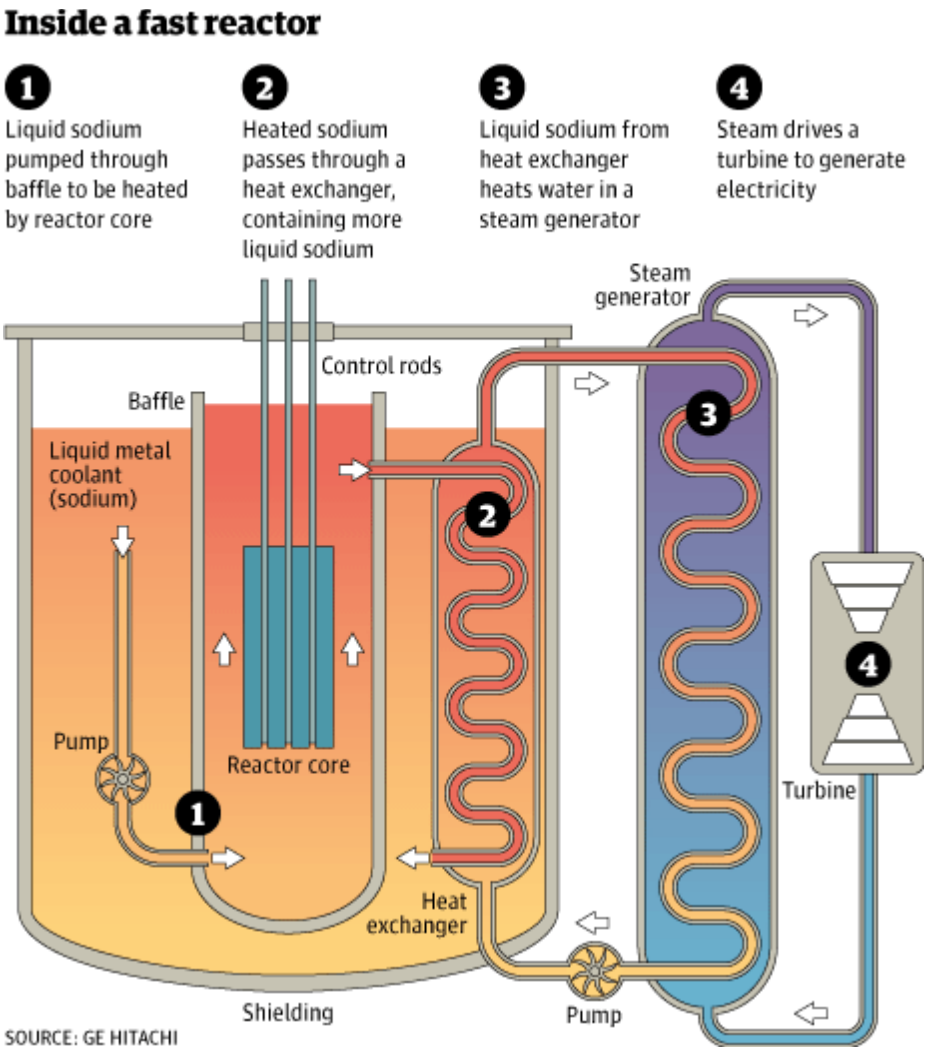
Breeder reactors use highly enriched fuels, which pose the danger of critical accidents. They also work at a very high temperature and a fast pace.

◆Plutonium persists for a long time in the environment, with a half-life of 24,000 years, and is highly toxic, causing lung cancer even if a small amount is inhaled.

◆The construction and operation is very costly. Between $4 to $8 billion is required in the construction alone.

◆The by

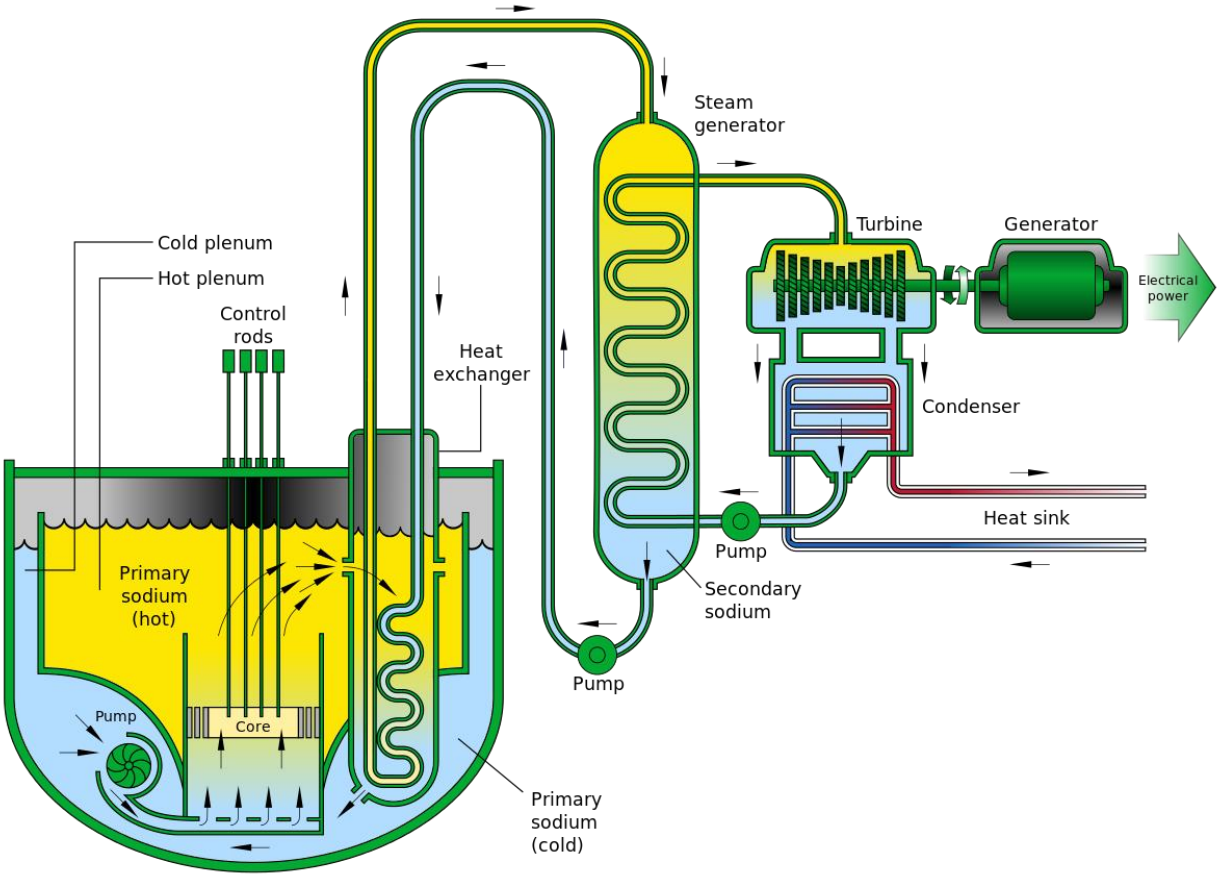
products formed during the fission of plutonium have to be removed by reprocessing, as they slow down the neutrons and reduce efficiency.

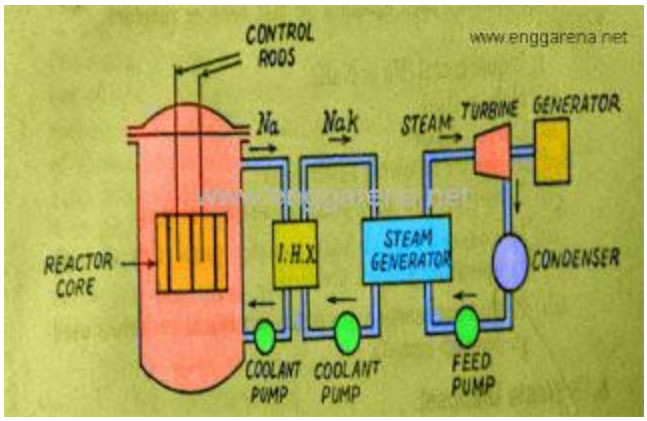


FAST BREEDER REACTOR

6 Explain Sodium- Graphite Reactor Advantages and Disadvantages

Ans: The sodium graphite reactor is a typical liquid metal reactor. The arrangement of the sodium graphite reactor power plant is shown in the figure.





Sodium Graphite Reactor Power Plant

It uses graphite as a moderator and liquid sodium as a coolant which reaches a temperature of about 850 degrees Celsius at a low pressure of only 7 bar.

In the primary circuit, the heat is absorbed by liquid sodium in the reactor. The sodium becomes radioactive while it passes through the core and reacts chemically with water.

Therefore, the heat absorbed by sodium is transferred to secondary coolant *sodium-potassium (NaK)* In the primary heat exchanger which in turn transfers the heat in the secondary heat

exchanger is called Steam generator. Water leaving the generator is converted into superheated steam up to a temperature of 540 degrees Celsius. This steam is used for power generation in the steam plant circuit in the usual manner.

The reactor vessel, primary circuit, and the primary heat exchanger have to be shielded from radiations.
The liquid metal is required to be handled under the cover of an inert gas like helium to prevent contact with air while charging or draining in the primary and secondary heat exchangers.

Advantages of Sodium Graphite Reactor (SGR) :

1. The high temperature of the steam can be obtained due to the use of liquid sodium as a coolant.

2. Thermal efficiency is high.

3. The system need not to be pressurized.

4. The cost of the pressure vessel and piping system is reduced due to the use of low-pressure sodium in the primary circuit.

Disadvantages of Sodium Graphite Reactor :

1. Any leakage of sodium coolant is highly dangerous.

2. Sodium is highly violent with air and water.

3. Primary and secondary heat exchangers are needed to be shielded with concrete blocks against radiations.

4. An intermediate heat exchanger is required to separate radioactive sodium with water and steam.

7 Explain Gas Cooled Reactor Advantages and Disadvantages:

Ans: A **gas-cooled reactor** (GCR) is a nuclear **reactor** that uses graphite as a neutron moderator and a **gas** (carbon dioxide or helium in extant designs) as coolant.

The Magnox reactor is named after the magnesium alloy used to encase the fuel, which is natural uranium metal.

Fuel elements consisting of fuel rods encased in Magnox cans are loaded into vertical channels in a core constructed of graphite blocks.
Further vertical channels contain control rods (strong neutron absorbers) which can be inserted or withdrawn from the core to adjust the rate of the fission process and, therefore, the heat

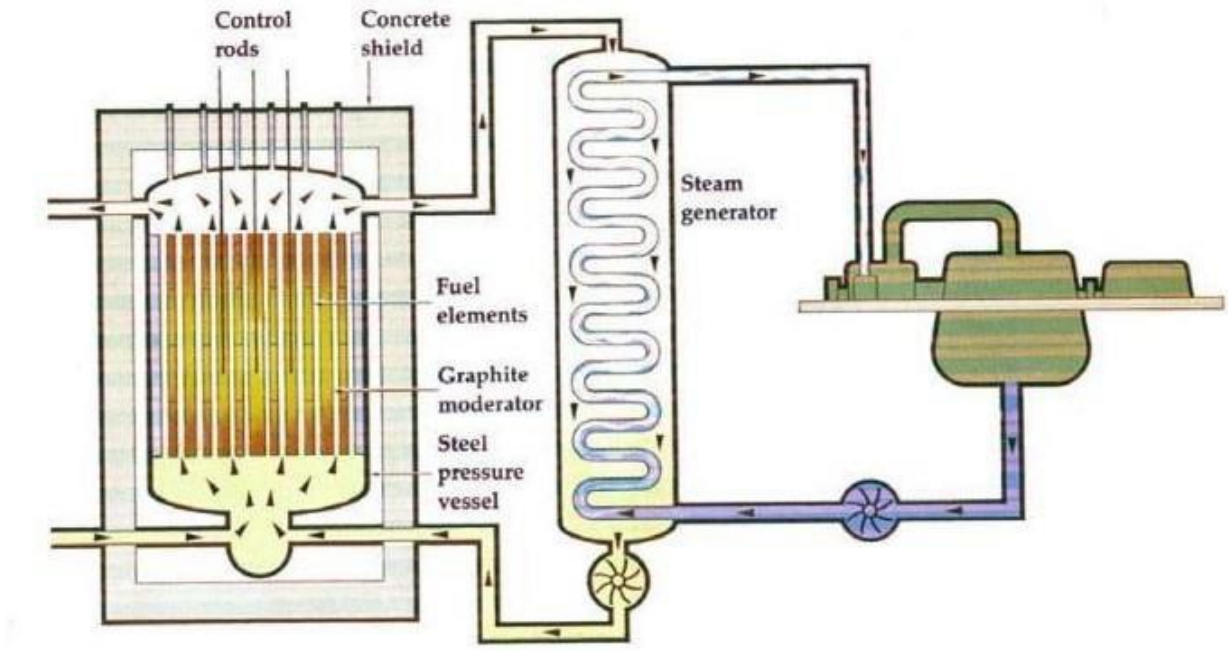
output. The whole assembly is cooled by blowing carbon dioxide gas past the fuel cans, which are specially designed to enhance heat transfer.

The hot gas then converts water to steam in a steam generator. Early designs used a steel pressure vessel, which was surrounded by a thick concrete radiation shield. In later designs, a dual-purpose concrete pressure vessel and radiation shield was used. In order to improve the cost effectiveness of this type of reactor, it was necessary to go to higher temperatures to achieve e higher thermal efficiencies and higher power densities to reduce capital costs.

This entailed increases in cooling gas pressure and changing from Magnox to stainless steel cladding and from Uranium metal to uranium dioxide fuel. This in turn led to the need for an increase in the proportion of U 235 in the fuel.

Gas-Cooled Reactor Advantages:- 1. Simple Fuel Process 2. No corrosion 3. Graphite – stable at high temperature 4. CO_2 eliminates the possibilities of explosion 5. Uranium carbide and graphite : resist high temperature

Gas-Cooled Reactor Disadvantages:- 1. Fuel : More Quantity and costly 2. Power density : very low 3. More Fuel (initially) : High Critical Mass 4. More power for coolant circulation 5. Complicated consolation



Gas Cooled Reactor

8.What is meant by Shielding and Radioactive waste disposal

Ans: Shielding the radioactive zones in the reactor roan possible radiation hazard is essential to protect, the operating men from the harmful effects.

During fission of nuclear fuel, alpha particles, beta particles, deadly gamma rays and neutrons are produced. Thick layers of lead or concrete are provided round the reactor for stopping the gamma rays. Thick layers of metals or plastics are sufficient to stop the alpha and beta particles.

Radioactive waste disposal:

Radioactive waste is waste that contains radioactive material. Radioactive waste is usually a by- product of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine.

Radioactive waste is hazardous to most forms of life and the environment, and is regulated by government agencies in order to protect human health and the environment.

Radioactivity naturally decays over time, so radioactive waste has to be isolated and confined in appropriate disposal facilities for a sufficient period until it no longer poses a threat. The time radioactive waste must be stored for depends on the type of waste and radioactive isotopes. Space disposal is attractive because it removes nuclear waste from the planet.

It has significant disadvantages, such as the potential for catastrophic(Involvng sudden great dmage) failure of a launch vehicle, which could spread radioactive material into the atmosphere and around the world. A high number of launches would be required because no individual rocket would be able to carry very much of the material relative to the total amount that needs to be disposed of. This makes the proposal impractical economically and it increases the risk of at least one or more launch failures.

9 What are the Advantages and Disadvantages of Nuclear power plant

Ans: The various advantages of a nuclear power plant are as follows:

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DISADVANTAGES

1. Initial cost of nuclear power plant is higher as compared to hydro or steam power plant.

2. Nuclear power plants are not well suited for varying load conditions.

3. Radioactive wastes if not disposed carefully may have bad effect on the health of workers and other population. In a nuclear power plant the major problem faced is the disposal of highly radioactive waste in form of liquid, solid and gas without any injury to the atmosphere. The preservation of waste for a long time creates lot of difficulties and requires huge capital.

4. Maintenance cost of the plant is high.

5. It requires trained personnel to handle nuclear power plants.