UNIT - II

Nuclear Power Stations

Location of Nuclear Power Plant:-

Availability of water:-

As sufficient water is required for cooling purposes, therefore the plant site should be located where ample quantity of water is available.

Disposal of waste:- The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazards. The waste should be either be buried in a deep trench or disposed off in sea quite away from sea shore. therefore the site selected for such a plant should have adequate arrangement for the disposal of waste.

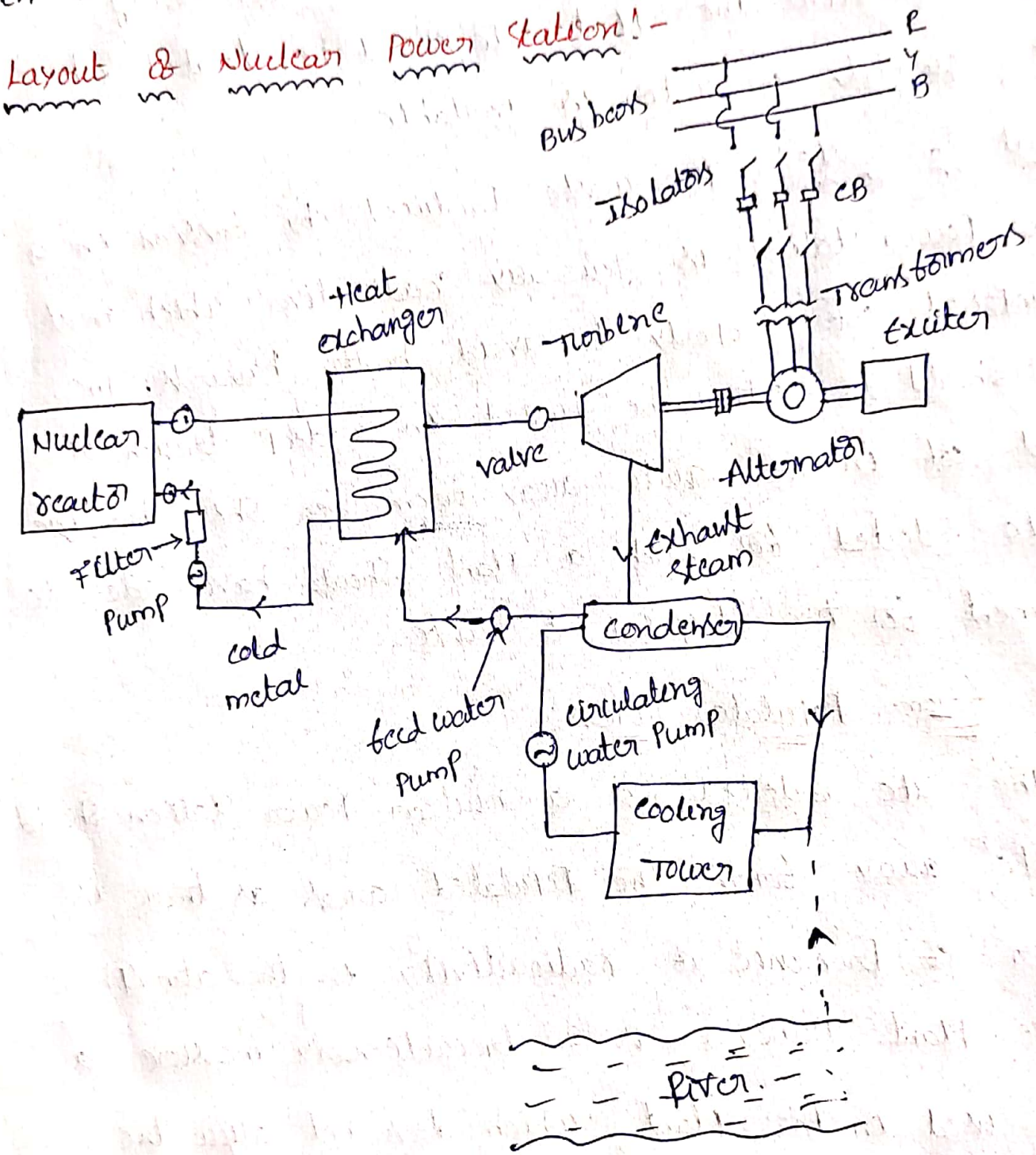
Distance from Populated areas:-

The site selected for a nuclear power station should be quite away from the populated areas as there is a danger of presence of radioactivity in the atmosphere near the plant. However as a precautionary measure, a dome is used in the plant which does not allow the radioactivity to spread by wind or underground water ways.

Transportation facilities!-

It should have adequate facilities in order to transport the heavy equipment during erection and to facilitate the movement of the workers employed in the Plant.

Layout of Nuclear Power station!-



The whole arrangement can be divided into 4 main stages.

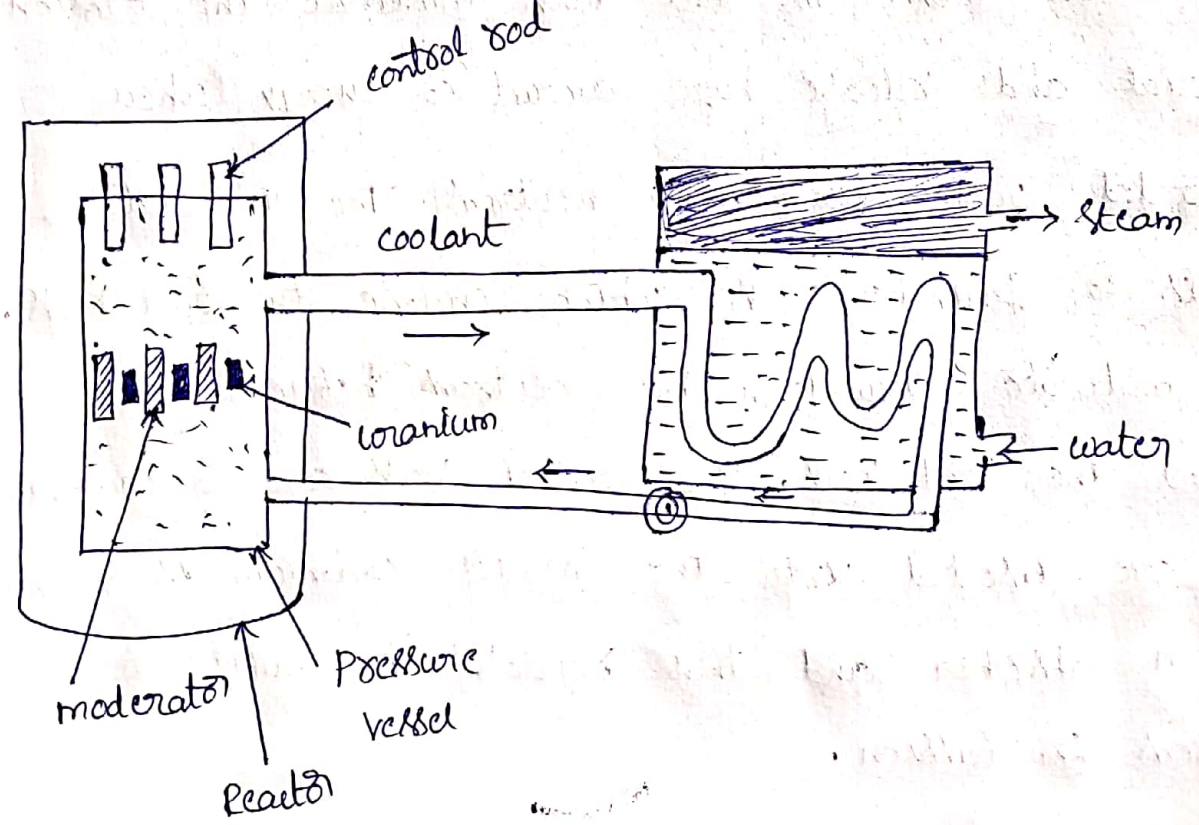
1) Nuclear Reactor 2) Heat exchanger 3) Steam turbine 4) Alternator

i) Nuclear reactor :-

It is an apparatus in which nuclear fuel (U^{235}) is subjected to nuclear fission. It controls the chain reaction that starts once the fission is done. If the chain reaction is not controlled, the result will be an explosion due to the fast increase in the energy released.

A Nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of uranium, moderator and control rods. The fuel rods constitute the fission material and release huge amount of energy when bombarded with slow moving neutrons. The moderator consists of graphite rods which enclose the fuel rods. The moderator slow down the neutrons before they bombard the fuel rods. The control rods are of cadmium and are inserted into the reactor. cadmium is strong neutron absorber and thus regulates the supply of neutrons for fission.

when control rods are pushed in deep enough, they absorb most of fission neutrons and hence few are available for chain reaction which therefore stops however as they are being withdrawn, more and more of these fission neutrons cause fission and hence the intensity of chain reaction is increased. therefore by pulling out the control rods, power of the nuclear reactor is increased. whereas by pushing them in, it is reduced. In actual practice the lowering or raising of control rods is accomplished automatically according to the requirement of load. The heat produced in the reactor is removed by the coolant. The coolant carries the heat to the heat exchanger.



Heat exchanger:-

The coolant gives up heat to the heat exchanger which is utilised in raising the steam. After giving up heat, the coolant is again fed to the reactor.

Steam turbine:-

The steam produced in the heat exchanger is led to the steam turbine through a valve. After doing a useful work in the turbine the steam is exhausted to the condenser. The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

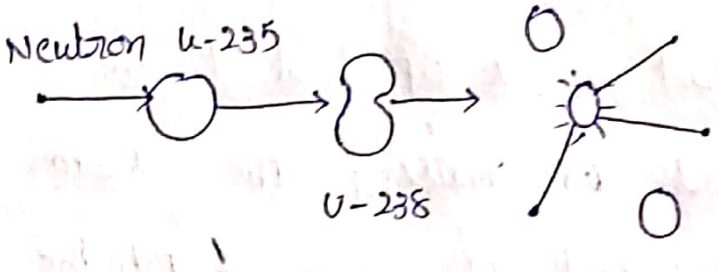
Alternator:- The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus-bars through transformers, circuit breakers and isolators.

Nuclear Fission:-

The splitting of a heavy nucleus into two or more smaller nuclei is termed nuclear fission. The process of fission is always accompanied by the ejection of two or more neutrons and liberation of vast energy.

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{139}_{56}Ba + {}^{94}_{36}Kr + 3{}^{1}_{0}n + \text{energy}$$

Ex!.



Fission Products.
Two Smaller Nuclei and
3 neutrons.

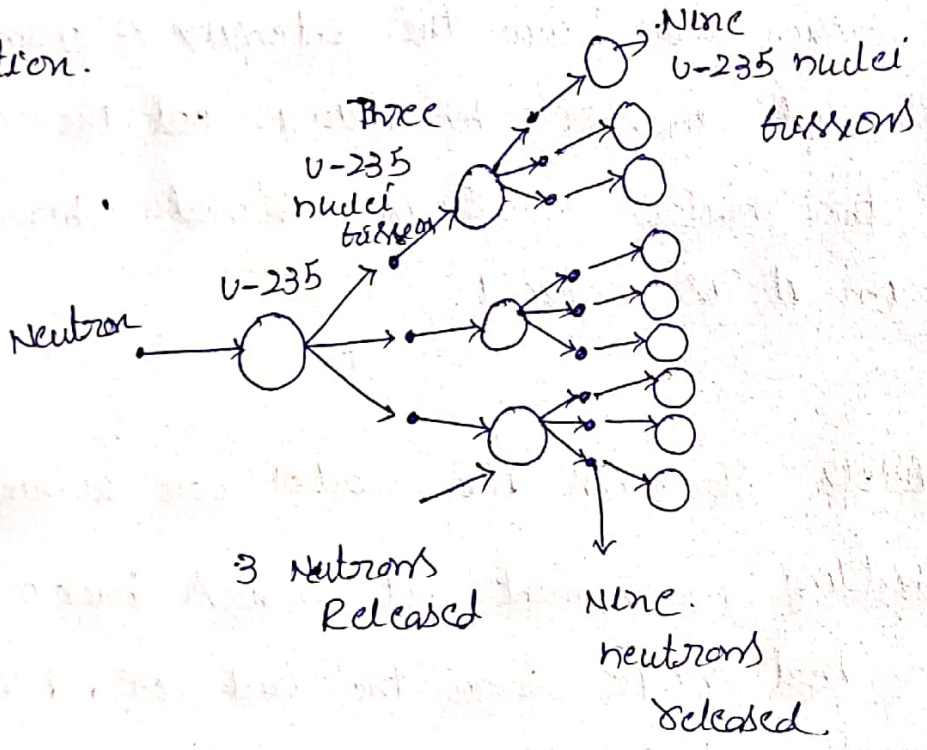
Nuclear Fuels:-

The fuels mainly used are natural uranium, enriched uranium, Plutonium and U-233, Natural uranium is the Parent material.

The materials U-235, U-233 and Pu-239 are called fissionable materials. The only fission able nuclear fuel occurring in natural uranium. of which 99.3% is $^{238}_{92}U$ and 0.7% as $^{235}_{92}U$ the other two fissionable materials ($^{239}_{94}Pu$ and $^{233}_{92}U$) can be Produced artificially from $^{238}_{92}U$ and $^{232}_{90}Th$ which occur in nature and are called fertile materials. out of the three fissionable materials.

Nuclear chain Reaction!-

Nuclear fission is done by bombarding uranium nuclei with slow moving neutrons. This split the uranium nuclei with the release of huge amount of energy and emission of neutrons. these fission neutrons cause further fission. if this process continues, then in a very short time huge amount of energy will be released which may cause explosion. this is known as explosive chain reaction.



Nuclear Reactor components!-

Moderator!-

The moderator slows down the neutrons before they bombard the fuel rods. and the moderator consists of graphite rods which enclose the fuel rods.

Control rods :-

The control rods are of cadmium and are inserted into the reactor. cadmium is strong neutron absorber and thus regulates the no. of neutrons for fission. When the control rods are pushed in deep enough. they absorb most of fission neutrons and hence few are available for chain reaction which, therefore, stops. However as they are being with drawn, more and more of these fission neutrons cause fission and hence the intensity of chain reaction is increased. therefore, by pulling out the control rods Power of the nuclear reactor is increased. where as by pushing them in, it is reduced.

Reflectors :-

This completely surrounds the reactor core within the thermal shielding arrangement and bounces back most of the neutrons that escape from the fuel core. this conserves the nuclear fuel, as the low speed neutrons thus returned are useful in continuing the chain reaction.

coolants :-

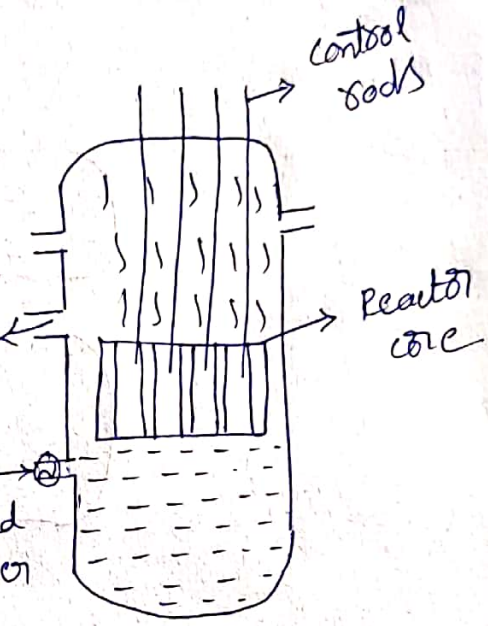
It is a medium through which the heat generated in the reactor is transferred to the heat exchanger for. further utilisation in Power generation. Sometimes when water is used as a coolant it takes up heat and gets

converted into steam. In the reactor which is directly used for driving system turbines.

Types of Nuclear Reactors:-

1) Boiling water Reactor
2) Pressurized water Reactor
3) Fast breeder Reactor.

1) Boiling water Reactor:-(BWR)



This is the simplest type of water Reactor. It has a steel Pressure vessel surranded by a concrete steam Sheild.

→ Ordinary water is used as both moderator and coolant.

→ The steam is generated on the Reactor it self.

→ Feed water enters the reactor vessel at the bottom and takes the heat produced due to fission fuel and gets converted into steam.

→ This steam leaves the Reactor at the top and after Passing through turbine and condenser Return to the Reactor.

Advantages:-

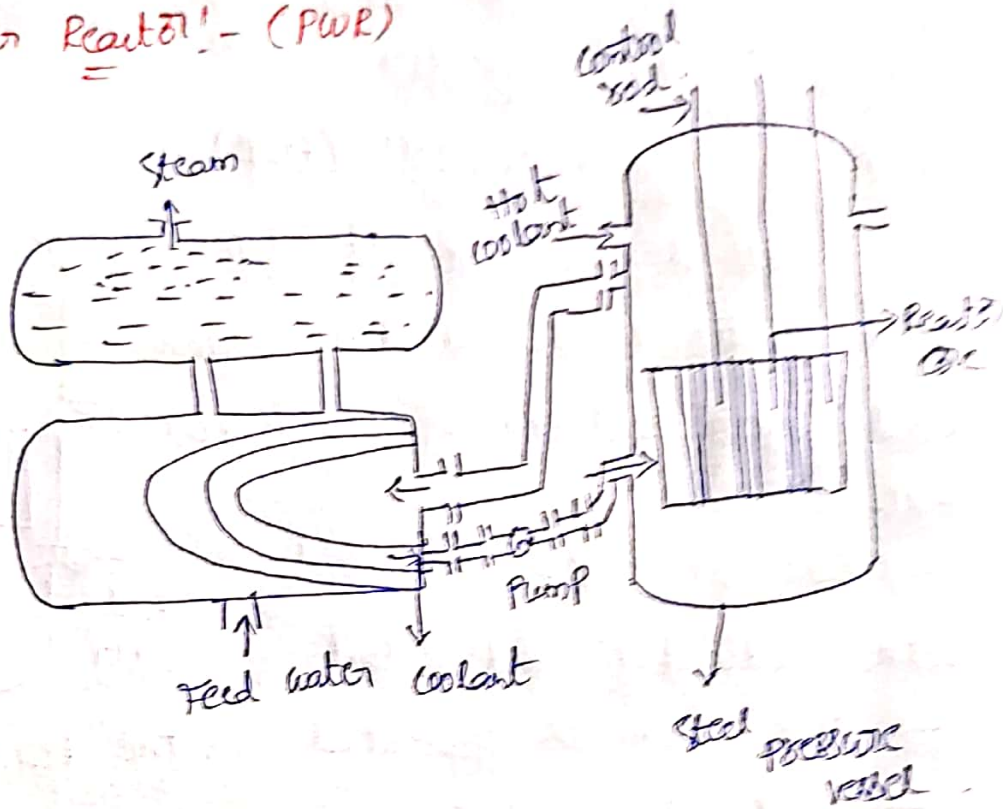
1) It requires small size
2) It doesn't requires heat exchanger circuit
3) In this the overall efficiency is about 33%.

Dis advantages :-

→ Due to direct cycle there is a danger of radio-active contamination of steam, so safety measures are to be provided.

→ It cannot meet a sudden increase in load.

Pressurized water Reactor :- (PWR)



* ~~Some of Water Reactor Operation~~

~~Advantages :-~~

→ It is a thermal Reactor using Enriched Uranium oxide, clad in Zircalloy as fuel.

→ The Pressure vessel is of steel. Water under Pressure is used both as coolant and moderator

→ The Pressure vessel and heat exchanger are Surrounded by a Concrete Steel.

→ In this reactor water is Pressurized to about 155°C atmosphere.

→ The hot water from the Reactor flows to a heat exchanger where its heat is transferred to the feed water to generated steam.

→ The steam is condensed in the condenser and the condensate steam Returns to heat exchanger forming a closed circuit.

Advantages:-

→ compactness, Possibility of breeding Plutonium.

→ High power density

→ cheap light water can be used as coolant

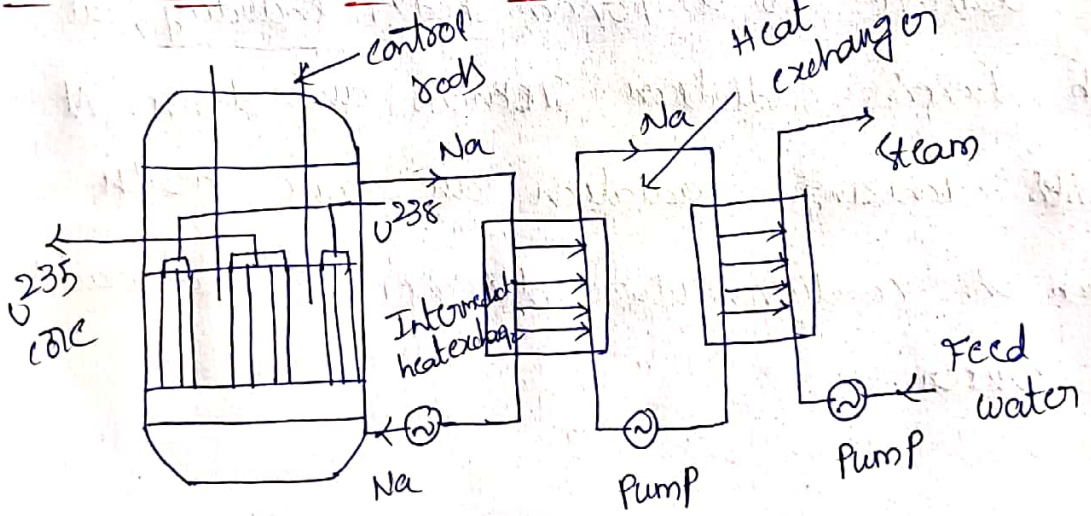
Dis advantages:-

→ High losses from heat exchanger

→ High Power consumption by auxiliaries

→ Formation of low temperature (250°c) steam.

Fast - Breeder Reactor (FBR):-



A fast breeder reactor is a small vessel in which the required quantity of enriched uranium or plutonium is kept without a moderator. The fissionable fuel core is surrounded by blanket of fertile material (U-238 or Th-232). The fertile material absorbs neutrons produced by the fissioning of U-235 and produces fissile material Pu-239 or U-233 respectively. Two heat exchangers are used. The reactor core is cooled by liquid metal. In the second heat exchanger the coolant is again Sodium/Potassium which transfers heat to feed water to generate steam.

Radiation Hazards :-

At high doses, ionizing radiation can cause immediate damage to a person's body, including, at very high doses radiation sickness and death. At lower doses, ionizing radiation can cause health effects such as cardiovascular disease and cataracts as well as cancer.

Shielding :-

→ Shielding is necessary to ground personnel and delicate instruments.

→ Various materials are used for shielding are (7) lead concrete, steel and cadmium.

→ Leads is common shielding materials, low cost.

→ concrete has efficiency lesser than lead.

→ Steel is not an efficiency shielding material but has good structural properties and is sometimes employed as an attending shield.

→ Cadmium is capable by absorbing slow neutrons.

→ This method does not completely prevent the radio activity from leading into the water.

Disposal of Nuclear waste:-

→ There are many ways for disposing of the solid fission products

→ The storing in shielded storage vaults consists in fixing the solid waste in boro-silicate glass and then storage of this glass in leak tight capsules.

→ These capsules or vaults can then be stored in deep salt mines or in deep wells drilled in the stable ocean floor.

→ Sometimes the Radiation waste filled in suitable containers and sunk to bottom of seas & oceans.