EEE 411
Power Station Engineering

NUCLEAR POWER PLANT

Nuclear Power Plant

*A generating station in which nuclear energy is converted into electrical energy is known as a **nuclear*** **power station.**

-**huge amount** of electrical energy from a relatively **small amount** of nuclear fuel as compared to other conventional types of power stations

-complete fission of **1 kg of Uranium** (U-235) can produce as much energy as can be produced by the **burning of 4,500 tons** of high-grade coal.

–Although the recovery of principal nuclear fuels (*i.e., Uranium and Thorium) is difficult and expensive,* yet **the total energy content** of the estimated world reserves of these fuels are considerably higher than those of conventional fuels, *viz., coal, oil and gas.*

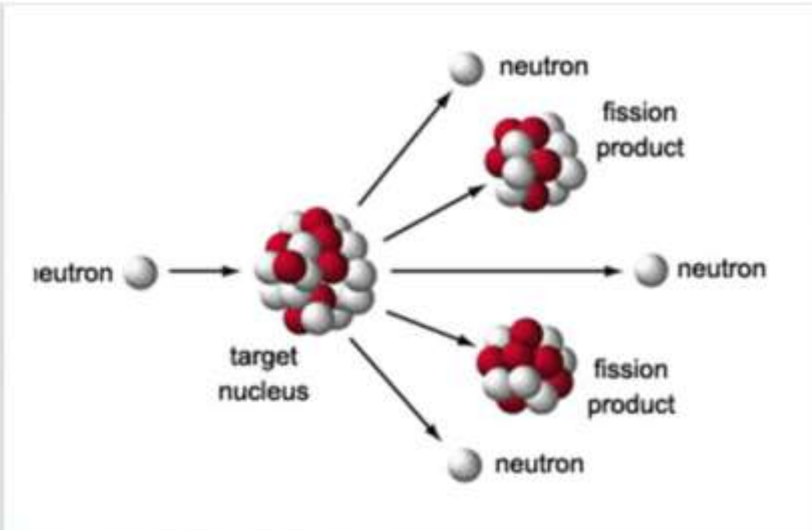
-At present, energy crisis is gripping us. So Nuclear power plant can be a **better alternative** .

Energy Comparison

Some Approximate data are given:

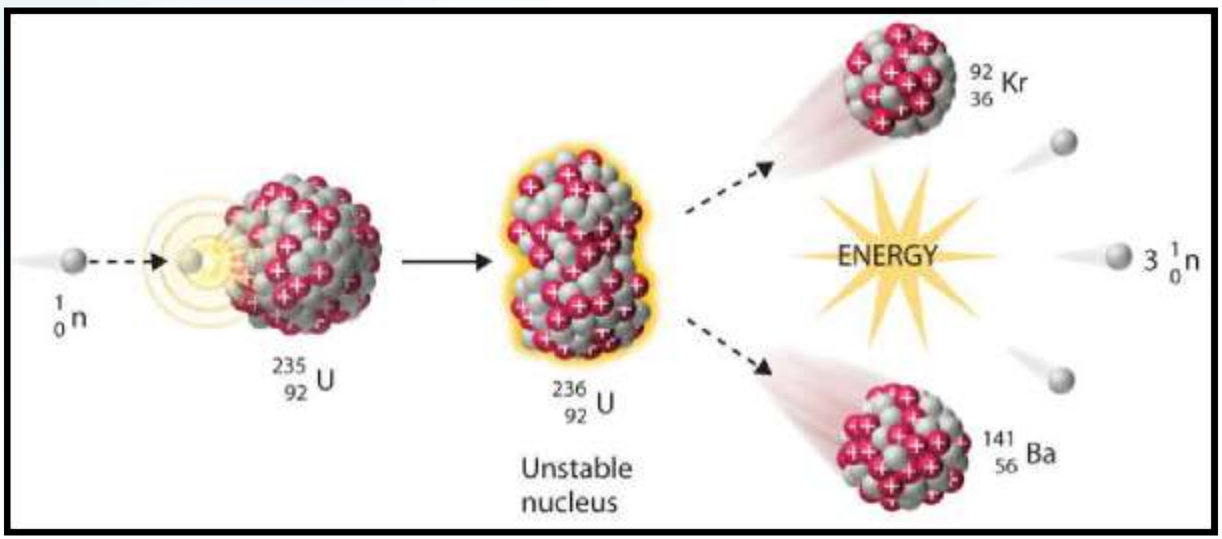
- **1 Kg coal** is equivalent to **3 KWh energy**
- **1 m^3 gas** is equivalent to **4 KWh energy**
- **1 Kg oil** is equivalent to **4 KWh energy**
- **1 Kg uranium** is equivalent to **50,000KWh energy** !!!

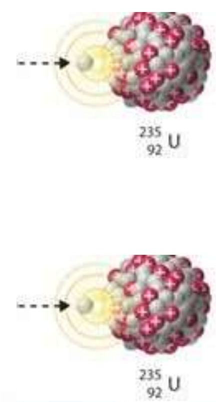
So what is Nuclear fission?



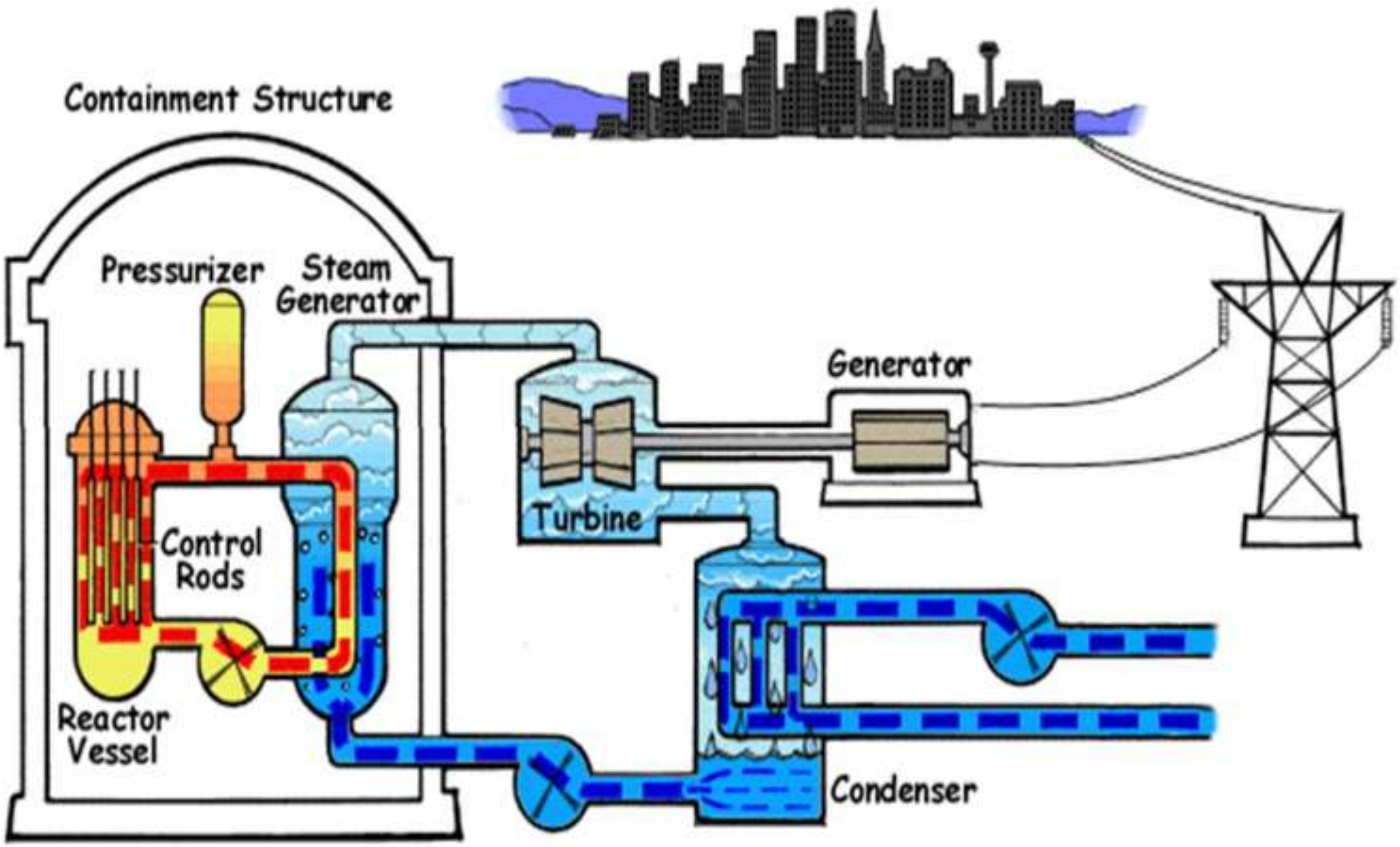
energy according to Einstein's equation.

$$E = mc^2$$

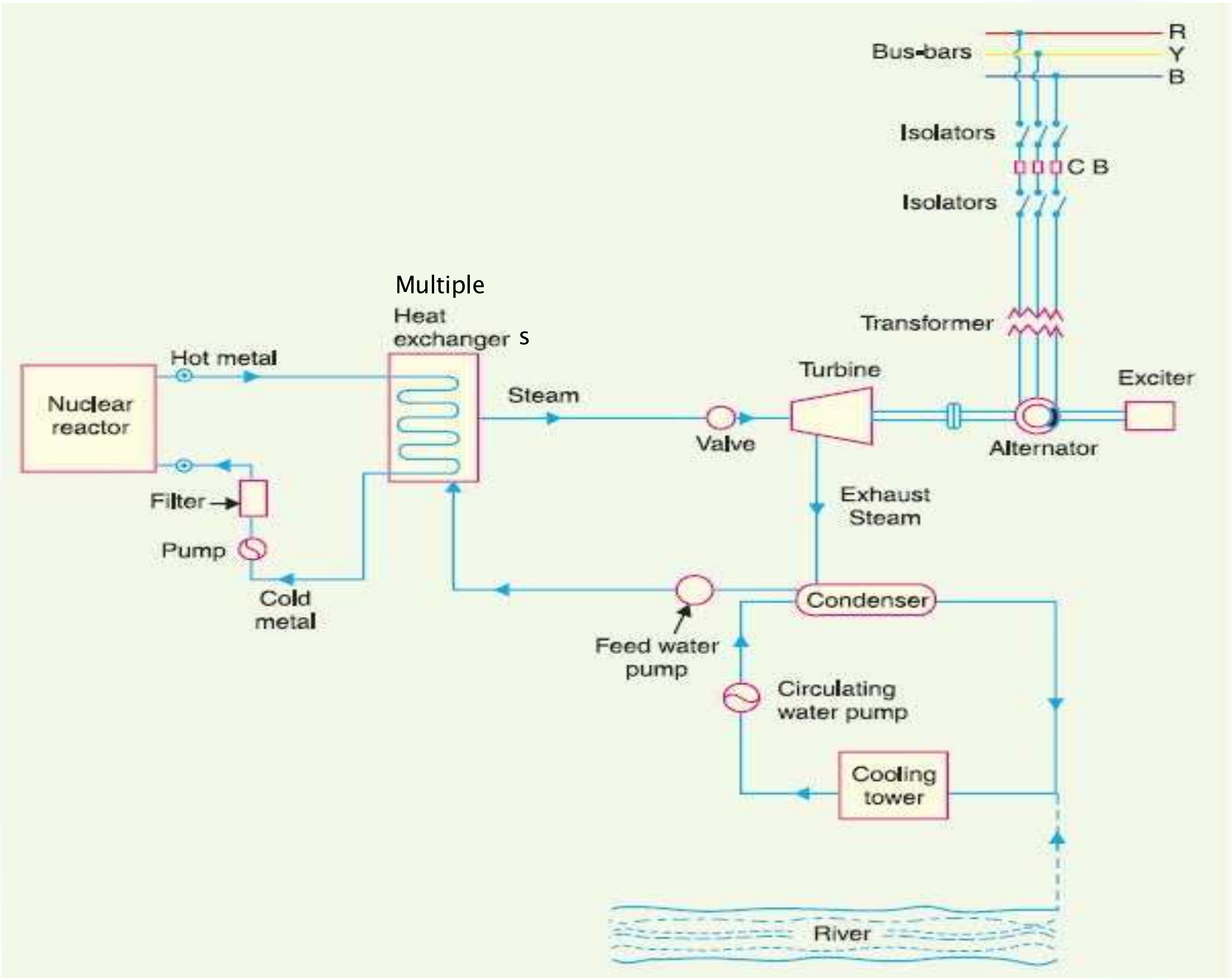




Working process



Schematic Diagram of a typical Nuclear Plant



Operations

–Heavy elements such as **Uranium** (U–235) or **Thorium** (Th–232) are subjected to **nuclear fission** in a special apparatus known as a ***reactor***

–Heat energy released is utilized in raising steam at high temperature and pressure

–The steam runs the **steam turbine** which converts **steam energy** into **mechanical energy**

–The turbine drives the alternator which converts **mechanical energy** into **electrical energy**

Components

1.Nuclear Reactor:

–An apparatus in which nuclear fuel (U-235) is subjected to nuclear fission.

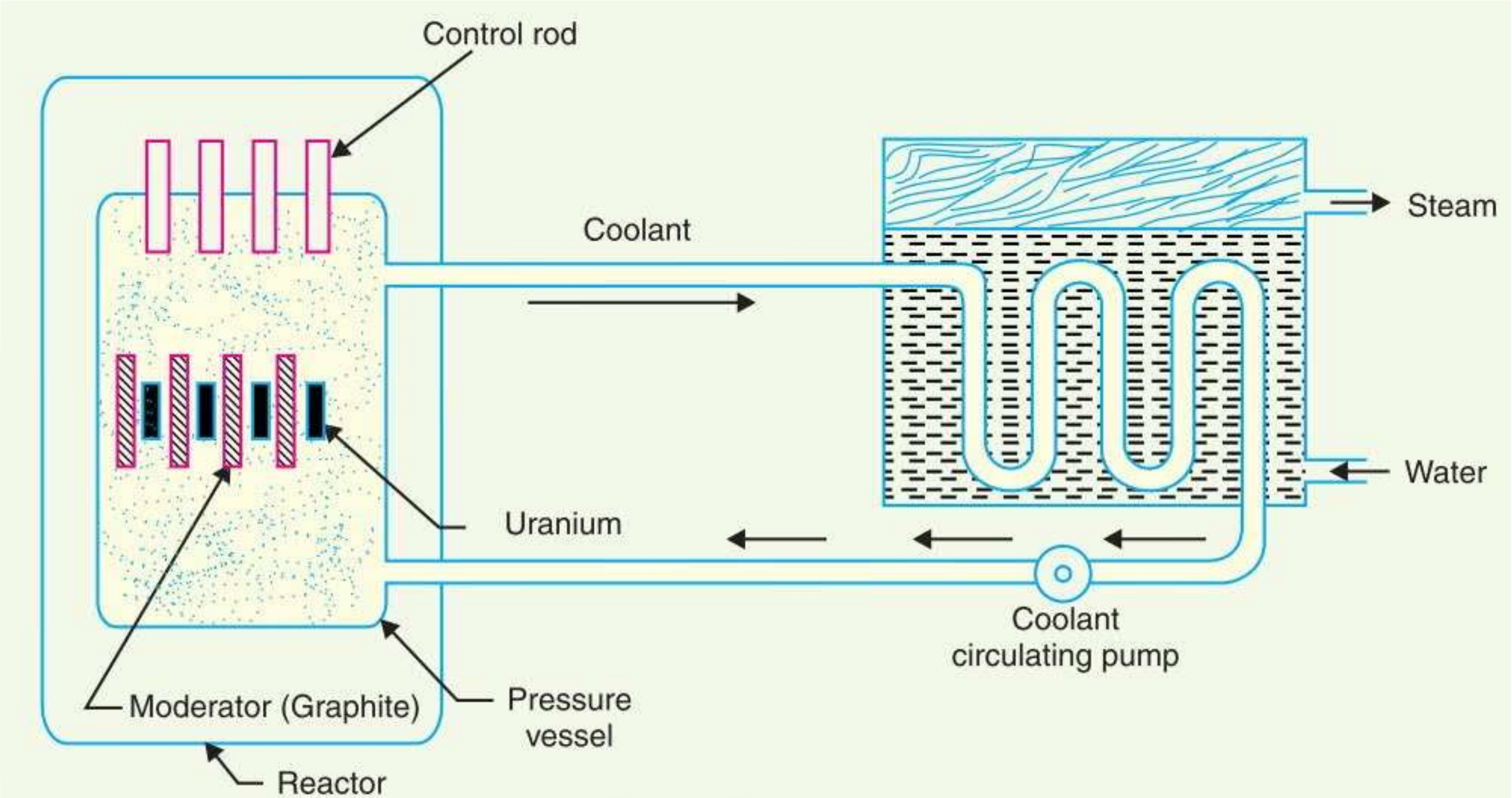
–Controls the *chain reaction that starts once the fission is done.*

–If the chain reaction is not controlled, the result will be an explosion due to the fast increase in the energy released.

–It is a cylindrical stout pressure vessel and contains:

i. Fuel rods
ii. Moderator
iii. Coolant
iv. Control Rods

1.Nuclear Reactor



Nuclear Reactor

1.Nuclear Reactor

i. Fuel Rods:

–Mainly Uranium is used .

–constitute the fission material and release huge amount of energy when bombarded with **slow moving** neutrons.

ii. Moderator:

–consists of graphite rods which enclose the fuel rods

–slows down the neutrons before they bombard the fuel rods

iii.Coolant: (A substance circulated through a nuclear reactor to remove or transfer heat)

–A coolant is a substance, typically liquid or gas, that is used to reduce or regulate the temperature of a system.

–Generally a sodium metal

–Heat produced in the reactor is removed by the coolant

–Coolant carries the heat to the heat exchanger

iv. Control Rods: (Typically Cadmium)

–strong neutron absorber and thus regulates the supply 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.

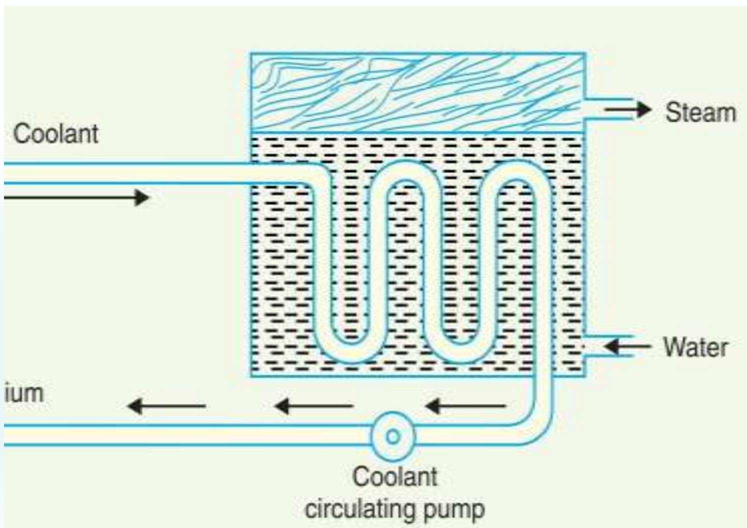
–However, as they are being withdrawn, more and more of these fission neutrons cause fission and hence the intensity of chain reaction (or heat produced) is increased.

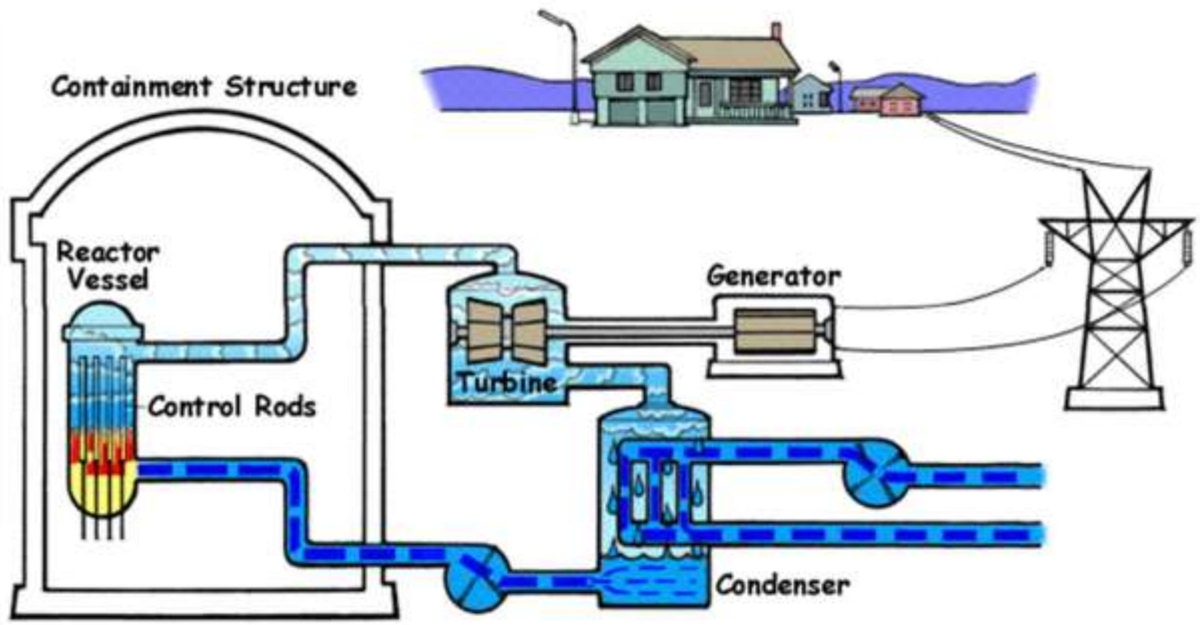
–pulling out the control rods, power of the nuclear reactor is increased.

–pushing them in, energy is reduced. In actual practice, pushing in or pulling out is done automatically as per load requirements.

2.Heat Exchanger

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





3.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 condenser

4.Condenser:

The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

5.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 transformer, circuit breakers and isolators

Notable Nuclear Power Plant Accident :

i. Fukushima, Onagawa and Tōkai (Japan) : On 11 March 2011
ii. Chernobyl disaster (Ukraine): worst accident in nuclear power history. on April 26, 1986
iii. Three Mile Island accident (USA): On March 28, 1979

Selection of Site

✓***Availability of water:*** as stated before, large amount of water is needed. So the plant should be located across a river or by seaside

✓***Disposal of waste*** *:* Waste is normally radio-active. So proper disposal is must. Waste should either be buried in a deep trench or disposed off in sea quite away from the seashore.

✓***Distance from populated areas:*** Isolated land is necessary due to safety from radio activity. as a precautionary measure, *a dome is used in the plant* which does not allow the radioactivity to spread by wind or underground waterways

✓***Transportation facilities:*** in order to transport the heavy equipment during erection and to facilitate the movement of the workers employed in the plant, adequate transportation system is necessary.

✓**Non-seismic zone:** The site should be placed at non-seismic zone. For the protection, 60–70 metre piling is done and pipes are placed under the earth above which the reactor is placed. So, the earthquake attacks mostly on the pipes.

Advantages

- The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation
- Requires less space as compared to any other type of the same size
- Low running charges as a small amount of fuel is used for producing bulk electrical energy
- Plant is very economical for producing bulk electric power
- Fuel is abundant and easy to transport so it can ensure continued supply of electricity
- Waste is compact and very smaller than coal generated waste.
- No acid rain or much air pollution

Disadvantages

- Fuel used is expensive and is difficult to recover
- Capital cost on a nuclear plant is very high as compared to other types of plants
- Fission by-products are generally radioactive and may cause dangerous radioactive pollution
- Maintenance charges are high and high salaries of specially trained personnel employed to handle the plant further raise the cost
- Not well suited for varying loads as the reactor does not respond to the load fluctuations efficiently.
- Disposal of the by-products, which are radioactive, is a big problem. They have either to be disposed off in a deep trench or in a sea away from sea-shore
- It may not only contaminate the environment but also do harm for many years. e.g. crops may be grown with radioactivity etc.

Mathematical Problems

Example 2.17. An atomic power reactor can deliver 300 MW. If due to fission of each atom of $_{92}U\text{–}235$, the energy released is 200 MeV, calculate the mass of uranium fissioned per hour.

Mathematical Problems

Example 2.18. What is the power output of a $_{92}U$–235 reactor if it takes 30 days to use up 2 kg of fuel? Given that energy released per fission is 200 MeV and Avogadro's number $= 6 \cdot 023 * 10^{26}$ per kilomole.

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