ME8792- POWER PLANT ENGINEERING

UNIT V-ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS

5.4-POLLUTION CONTROL TECHNOLOGIES FOR NUCLEAR POWER PLANTS.

SELECTION OF SITE FOR NUCLEAR POWER PLANT

The various factors to be considered while selecting the site for nuclear plant are as follows :

1. **Availability of water**. At the power plant site an ample quantity of water should be available for condenser cooling and made up water required for steam generation. Therefore the site should be nearer to a river, reservoir or sea.

2. **Distance from load center**. The plant should be located near the load center. This will minimise the power losses in transmission lines.

3. **Distance from populated area.** The power plant should be located far away from populated area to avoid the radioactive hazard.

4. **Accessibility to site.** The power plant should have rail and road transportation facilities.

5. **Waste disposal.** The wastes of a nuclear power plant are radioactive and there should besufficient space near the plant site for the disposal of wastes.

POLLUTION CONTROL TECHNOLOGIES INCLUDING WASTE DISPOSALOPTIONS FOR NUCLEAR POWER PLANTS

Nuclear power is classified as a clean energy source because of absence of noxious combustion products and the supply of fuel which will last for centuries when breeder reactors become operational. The nuclear power generation poses mainly two problems as follows.

(i) The management of radioactive waste, and

(ii) The danger passed in case of accident is very high and long standing.

The radioactive emission during the operation of the power plant is negligible but the emission intensity is very high which comes out from wastes. They emit large quantities of γ-rays which are very danger for living matters.

The radioactive waste coming out of 400 *MW* power plant would be equal to 100 *tons* of radium daily. This much of radioactive waste disposed to the atmosphere would kill all living organisms within the area of about 100 *square kilometers*. Therefore, safe disposal of nuclear waste is a major problem and it is very much essential. Many numbers of methods are developed for the last 25*years* to dispose off various types of nuclear waste safely.

TYPES OF NUCLEAR WASTES

The nuclear wastes are classified as follows.

(i) On the basis of half-life time

(a) Fission products

(b) Actirides

(c) The neutron activation products.

(ii) On the basis of the intensity of radiation

(a) Low level waste

(b) Medium level waste

(c) High level waste.

1. Fission products:

The wastes produced from reactor operations include fission products and Plutonium. The half-lives of most of the fission products are 30 *years* or less. Their toxic lifetime is in the order of 500 *years* to 1000 *years*. Most of the fission products are initially radioactive and decay with the emission of β and γ-rays.

2. Actinides:

Actinides are produced in nuclear reactors as a result of neutron capture by Uranium. The most important is Plutonium. The other actinides are neptunium, americium and curium. The actinides decay mainly by emission of α-particles until a stable isotope of load is formed.

α-particles can be easily stopped. Therefore, actinides do not require thick shieling. However, α-particles are very energetic and toxic if inhaled as dusts.

3. Neutron activation products:

These are produced when fast neutrons are absorbed by structural materials in reactors as coolant, fuel cladding etc. These products decay with the emissions of β and γ radiations.

4. Low level wastes:

Low level wastes contain less than 10 *nanocuries per gram* of trans uranium contaminants. They have low but potentially hazardous concentration of radioactive materials. Low level wastes are produced in almost all activities such as power generation, medical, Industrial etc. They involve with radioactive materials. They require little or no shielding and they are usually disposed off in liquid form through shallow land burial.

5. Medium level wastes:

Medium level wastes contain more than 10 nanocuries but they are less than 100 nanocuries per *gram* of trans uranium contaminants. These wastes are mainly contaminated with neutron activation product isotopes.

6. High level wastes:

The high level wastes contain more than 100 *nanocuries per gram* of trans uranium contaminants. These are generated by reprocessing of spent fuel. The spent fuel is withdrawn from the reactor and placed in a water pond. The heat is removed from the water pond. The pond wastes are continually treated to remove activity due to release of fuel from defective cladding. The spent fuel is then transferred to the reprocessing plant where the cladding contains the fuel to be removed and the fuel is dissolved in nitric acid. U^{235} and Pu^{239} are then removed around 99% non-volatile fission products behind in solution known as "***highly active liquid waste***".

Effects of High-Level Wastes

It is important to study the effects of high level wastes to biological systems. The principle effect is the destruction of body cells in the vicinity of the irradiated region due to interaction of the radiation and tissue. The interaction between radiation and tissue is manifested in three ways.

1. Ionization:

The formation of ion-pair in tissue requires $32.5eV$ of energy when a single $1Mev$ β-particle is stopped by tissue about 3100 *ion-pairs* formed. If $1cm^2$ area of tissue surface is subjected to a beam of β-particles/cm^2/s, 31×10^6 *ion-pairs* will be formed in each second. This absorption results the complete damage of tissues in the body of man or beast or bird.

2. Displacement:

If the energy of the impinging particle is sufficiently high, an atom in the tissue is displaced from its normal lattice position with possible adverse effects. Neutron and γ-radiation result the atomic displacement.

3. Absorption:

Absorption of neutron by a tissue nucleus results the formation of a radioactive nucleus and it changes the chemical nature of the nucleus. It causes malfunctioning of the tissue cell and the cell damage causes severe biological effects including genetic modifications.

NUCLEAR WASTE DISPOSAL

These wastes must be disposed off in such a manner that there is no harm to human, animal or plant lives. Solids of low and medium level wastes are buried at a depth of few meters at carefully selected sites. Gaseous wastes are discharged to the atmosphere through high stacks. Liquids having low or medium level of radioactivity are given preliminary treatment to remove the most of activity in the form of solid precipitate and then it is discharged in dry wells or deep pits. Different methods for various nuclear wastes disposed are discussed below.

Disposal of Low Level Solid Waste

Low level solid waste requires little or no shielding. It is usually disposed off by keeping it in a steel or concrete tank. These tanks are buried either few meters below the soil or kept at the bed of the Ocean shown in Figure

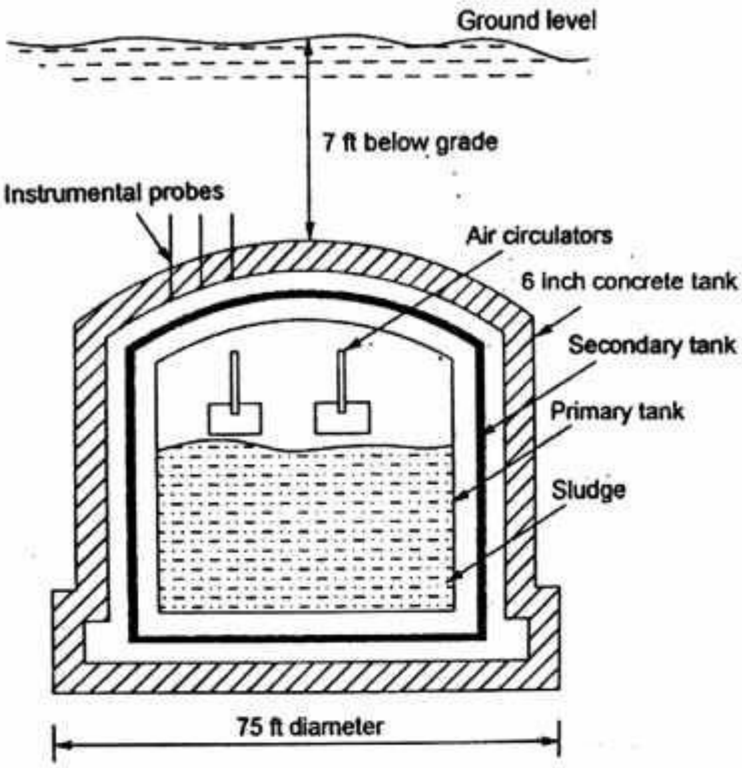


Figure ***Disposal of low level solid waste***

Disposal of Medium Level Solid Wastes

Medium level wastes are mainly contaminated with neutron activation product isotopes. They are incorporated into cement cylinders. Cement is non-combustible material and it provides shielding against the external exposure. Cement is also having the ability of resistance to reach by ground water.

Disposal of High Level Wastes

Spent fuel from the nuclear reactor can either be stored directly or reprocessed. The storage system avoids the cost and hazards associated with a reprocessing plant. The second method utilizes reprocessing of unused uranium and converted into Plutonium and other radioisotopes for the use in wide variety of services such as isotope generators, medicine, agriculture and industry.

Reprocessing of the spent fuel is done by dissolving it in nitric acid and then removing the converted Plutonium and unspent uranium by solvent extraction. The remaining solution contains more than 99.99% of the non-volatile fission products plus some constituents of the cladding of fuel elements, traces of plutonium and Uranium.

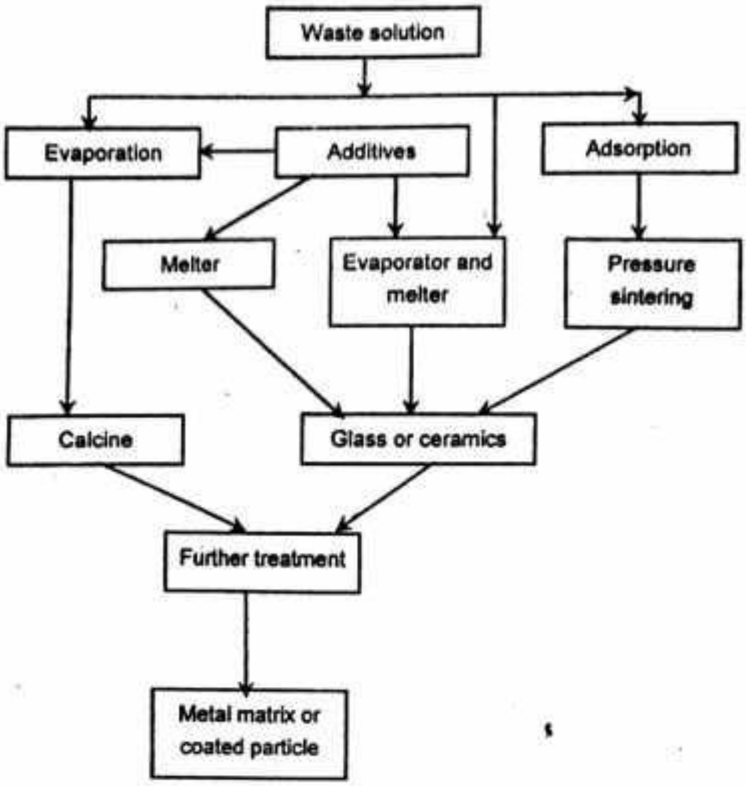


Figure 5.30 Basic high level waste solidification processes

The remaining solution consists of high level wastes. It is usually concentrated by evaporation. It is then stored as an aqueous nitric acid solution usually in high integrity stainless steel tanks. However, the permanent storage in liquid form requires continuous supervision and tank replacement over an indefinite period of time.

The conversion of the liquid wastes to a solid form is very important. It avoids leakages. It requires less supervision and it is more suitable for final disposal. Advanced processes are currently being developed. This solid product should maintain its mechanical strength. Ideally, it should have a low leak rate.

Glasses and ceramics are now considered to be most suitable forms for this final disposal. The basic processes are shown in Figure 5.30. It involves in evaporation and de-nitration (or calcinations) to form a granular or solid calcine. It is considered an interim product since it does not meet all above requirements. It is treated further by being mixed with additives and it is then melted to form glasses or ceramics.

A second process involves mixing of additives with the original waste solution, evaporating, de-nitrating and melting this mixture to form glasses or ceramics.

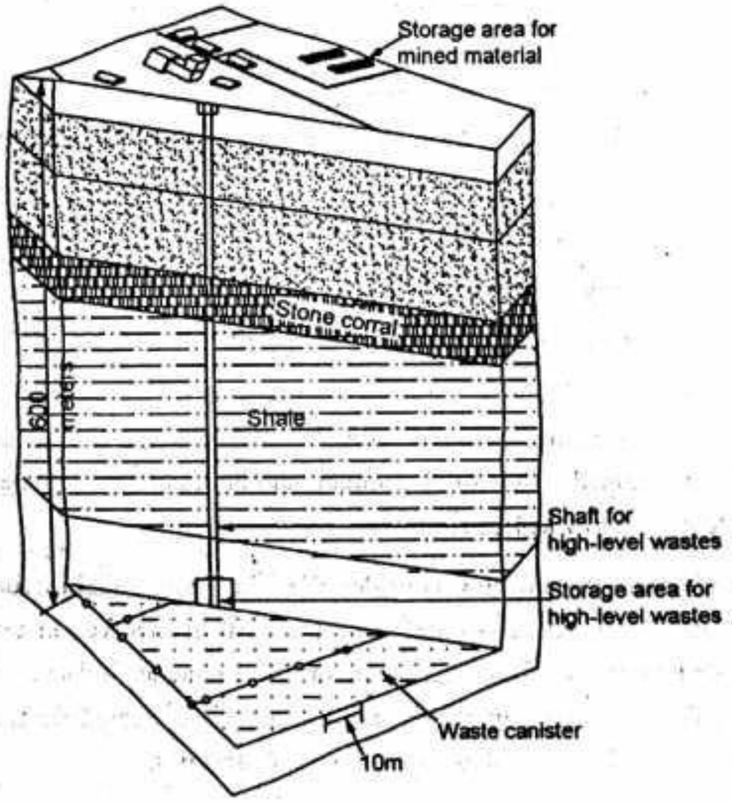
A third process uses an adsorption process and treatment at high temperature to produce ceramics.

Most solidification plants produce steam from off-gases and oxides of nitrogen that usually contain some fine particulate carryover and volatile radio-nuclides. These gases must be treated. All processes involve high temperature as well as high level of radioactivity.

Underground Disposal of High Level Waste

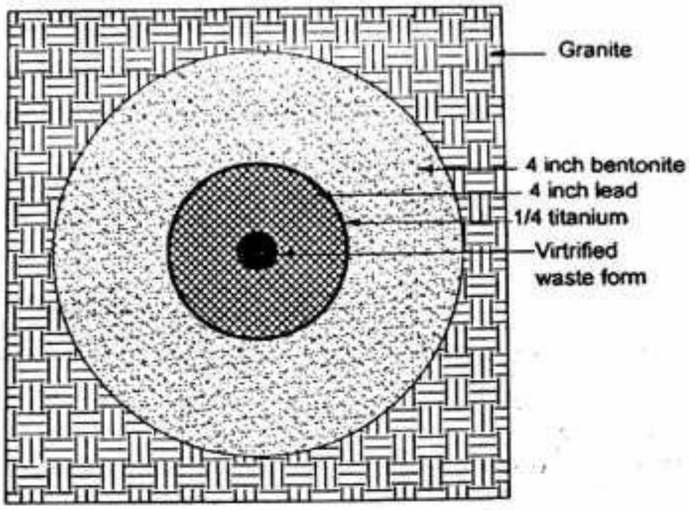
The final disposal of wastes with or without above treatments is also a major concern. Many countries are undertaking activities involving underground disposal in deep geological formation. These activities include the investigation of suitable sites and suitable methods of storing in these sites.

The main objectives are the protection of present and future populations from potential hazards. The suitable sites must be free of flowing ground wastes but the storage vessels must demonstrate the reliability even in flowing condition.



Underground disposal of high level nuclear waste

A cavity is excavated 511*m* depth in salt mine and cylinders are stored in this cavity as shown in Figure 5.31. It has a special advantage that the salt is strong absorber of radioactive emissions and it has good thermal conducting property which helps to keep the temperature within the acceptable limit.



Nuclear Solid waste in canister

The solidified waste is placed in canisters which are stored in holes drilled in rock salt with a spacing of about 10 *m* to allow for the efficient dissipation of energy without exceeding the permissible temperature limits of salt in canisters. Each canister will require about 100 m^2 of salt for cooling.

Figure 5.32 shows the cross-section of a canister of Swedish design for the disposal in granite. It shows the vitrified waste surrounded by 4 inch of lead, 0.25 inch of titanium, 4 inch of bentonite and finally granite.