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LIQUID AND SOLID RADWASTE MANAGEMENT IN PRESSURISED HEAVY WATER REACTOR BASED NUCLEAR POWER PLANTS

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FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective to ensure safety of members of the public and occupational workers, as well as protection of environment, the Atomic Energy Regulatory Board has been entrusted with the responsibility of laying down safety standards and framing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety standards, codes of practice and related guides and manuals for the purpose. These documents cover aspects such as siting, design, construction, operation, quality assurance, decommissioning and regulation of nuclear and radiation facilities.

Codes of practice and safety standards are formulated on the basis of internationally accepted safety criteria for design, construction and operation of specific equipment, systems, structures and components of nuclear and radiation facilities. Safety codes establish the objectives and set minimum requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised, when necessary, in the light of the experience and feedback from users as well as new developments in the field.

The 'Code of Practice on Design for Safety in Pressurised Heavy Water Reactor Based Nuclear Power Plants (AERB/SC/D, 1989)' lays down the minimum requirements for ensuring adequate safety in plant design. This Safety Guide is one of a series of guides, which have been issued or are under preparation, to describe and elaborate the specific parts of the Code.

One of the requirements in designing a nuclear power plant is safe management of liquid and solid radwaste generated during the operation. This Guide addresses various design features involved in the design and construction of the waste management facility. In drafting it, extensive use has been made of the information contained in the relevant documents of the International Atomic Energy Agency issued under its Nuclear Safety Standards (NUSS) Programme.

Consistent with the accepted practice, 'shall', 'should' and 'may' are used in the Guide to distinguish between a firm requirement, a recommendation and a desirable option, respectively. Appendices are an integral part of the document, whereas annexures, footnotes, references/bibliography and lists of participants are included to provide information that might be helpful to the user. Approaches for implementation, different to those set out in the Guide, may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public and protection of the environment.

For aspects not covered in this Guide, applicable and acceptable national and international standards, codes and guides should be followed. Non-radiological aspects of industrial safety and environmental protection are not explicitly considered. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

This Guide has been prepared by specialists in the field drawn from the Atomic Energy Regulatory Board, Bhabha Atomic Research Centre, Indira Gandhi Centre for Atomic Research and Nuclear Power Corporation of India Limited. It has been reviewed by the relevant AERB Advisory Committee on Codes and Guides and the Advisory Committee on Nuclear Safety.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.

(Suhas P. Sukhatme)
Chairman, AERB

DEFINITIONS

Acceptable Limits

Limits acceptable to the Regulatory Body for accident condition or potential exposure.

Activity

The quantity 'A' for an amount of radionuclide in a given energy state at a given time, defined as:

$A = dN/dt$

where, dN is the expectation value of the number of spontaneous nuclear transformations from the given energy state in a time interval dt. The SI unit of activity is the reciprocal of second (s^{-1}), termed the Becquerrel (Bq).

ALARA

An acronym for "As Low As Reasonably Achievable". A concept meaning that the design and use of sources and the practices associated therewith, should be such as to ensure that exposures are kept as low as reasonably practicable, economic and social factors being taken into account .

Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear facility and to perform safety and regulatory functions including enforcement for the protection of the public and operating personnel against radiation.

Authorised Limits

See 'Prescribed Limits'.

Authorisation

A type of regulatory consent issued by the Regulatory Body for all sources, practices and uses involving redioactive materials and rediation generating equipment (see also 'Regulatory Consent').

Clearance Levels

A set of values established by the Regulatory Body and expressed in terms of activity concentrations and/or total activity, at or below which sources of radiation may be released from regulatory control.

Competent Authority

Any official or authority appointed, approved or recognised by the Government of India for the purpose of the Rules promulgated under the Atomic Energy Act 1962.

Conditioning of Wastes

Those processes that transform waste into a form suitable for transport and/or storage and/or disposal. These may include converting the waste to another form, enclosing the waste in containers and providing additional packaging.

Consent

A written permission issued to the consentee, by the Regulatory Body to perform the specified activities related to nuclear and radiation facilities. The types of consent are ‘License’, ‘Authorisation’, ‘Registration’, and ‘Approval’ and will apply depending upon the category of the facility, the particular activity and radiation source involved.

Contamination

The presence of radioactive substances in or on a material in the human body or other places in excess of quantities specified by the Competent Authority.

Criteria

Principles or standards on which a decision or judgement can be based. They may be quantitative or qualitative.

Critical Group

A group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source. When exposure occurs by more than one pathway, the term may also be used to mean the group which receives the highest total doses by all the pathways of exposure from a given source or practice.

Decommissioning

The process by which a nuclear or radiation facility is finally taken out of operation, in a manner that provides adequate protection to the health and safety of the workers, the public and of the environment.

Decontamination

The removal or reduction of contamination by physical or chemical means.

Discharge Limits

The limits prescribed by the Regulatory Body for effluent discharges into atmosphere aquatic environment from facilities.

Disposal

The emplacement of waste in a repository without the intention of retrieval or the approved direct discharge of waste into the environment with subsequent dispersion.

Effluent

Any waste discharged into the environment from a facility either in the form of liquid or gas.

Exempt Waste

Waste, which is cleared from regulatory control in accordance with clearance levels. The designation should be in terms of activity concentration and/or total activity and may include a specification of the type, chemical/physical form, mass or volume of waste.

High Level Waste (HLW)

It is a type of waste which contains any of the following aspects :-

- The radioactive liquid containing most of the fission products and actinides present in spent fuel, which forms the residue from the first solvent extraction cycle in reprocessing and some of the associated waste streams;

- Solidified high level waste from above and spent reactor fuel (if it is declared a waste); or
- Any other waste with similar radiological characteristics.

Inspection

Quality control actions which by means of examination, observation or measurement determine the conformance of materials, parts, components, systems, structures as well as processes and procedures with pre-determined quality requirements.

Institutional Control (Radioactive Waste)

The process of Controlling radioactive waste site by an authority or institution designated under the laws of a country. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a nuclear/radiation facility.

Intermediate Level Waste (ILW)

Radioactive Waste in which the concentration or quantity of radionuclides is above that of low level waste but below that those of HLW, with the thermal power below those of HLW. It requires shielding during handling and transportation. Thermal power of ILW is below 2 kW/m^3.

Licence

It is a type of regulatory consent, granted by the Regulatory Body for all sources, practices and uses for nuclear facilities involving the nuclear fuel cycle and certain categories of radiation facilities. It also means authority given by the Regulatory body to a person to operate the above said facilities.

Long-lived Wastes

Radioactive wastes containing long-lived radionuclides having sufficient radiotoxicity and/or concentrations requiring long time isolation from the biosphere. The term long-lived radionuclides refers to half-lives usually greater than 30 years.

Low-Level Waste (LLW)

Radioactive waste in which the concentration or quantity of radionuclides is above clearance levels established by the regulatory body but with the radionuclide content below those of intermediate and high level wastes. It does not require shielding during handling and transportation.

Low and Intermediate Level waste (LILW)

Radioactive wastes in which the concentration or quantity of radionuclides is above clearance levels established by the regulatory body, but with a radionuclide content and thermal power below those of high level waste. Low and intermediate level waste is often separated into short lived and long lived wastes.

Monitoring

The continuous or periodic measurement of parameters for reasons related to the determination, assessment in respect of structure, system or component in a facility or control of radiation.

Near Surface Disposal

Disposal of waste with/without engineered barriers, or below the ground surface with adequate final protection covering to bring the surface dose rate within acceptable limits.

Nuclear Facility

All nuclear fuel cycle and associated installations encompassing the activities covering from the front end to the back end of nuclear fuel cycle processes and also the associated industrial facilities, such as, heavy water plants, beryllium extraction plants, zirconium plant, etc.

Nuclear Power Plant

A nuclear reactor or a group of reactors together with all the associated structures, systems, equipment and components necessary for safe generation of electricity.

Operation

All activities following commissioning and before decommissioning performed to achieve, in a safe manner, the purpose for which an nuclear/radiation facility was constructed, including maintenance.

Pre-treatment (Radioactive Waste)

Any operation/conditioning of waste prior to final treatment before disposal.

Prescribed Limits

Limits established or accepted by the Regulatory Body.

Quality Assurance

Planned and systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service as per design specifications.

Radioactive Waste[1]

Material, whatever its physical form, remaining from practices or interventions and for which no further use is foreseen (a) that contains or is contaminated with radioactive substances and has an activity or activity concentration higher than the level for clearance from regulatory requirements, and (b) exposure to which is not excluded from regulatory control.

Regulatory Body

See 'Atomic Energy Regulatory Board (AERB)'.

Regulatory Consent

See Consent

Responsible Organisation

The organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

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1 For the purpose of this guide the term 'Radwaste' synonymously means 'Radioactive waste'.

Safety Assessment

A review of the aspects of design and operation of a source which are relevant to the protection of persons or the safety of the source, including the analysis of the provisions for safety and protection established in the design and operation of the source and the analysis of risks associated with normal conditions and accident situations.

Safety Analysis

The evaluation of the potential hazards (risks) associated with the implementation of a proposed activity.

Secondary Waste

A form and quantity of waste that results as a by-product of the process from applying a waste treatment technology to the initial waste.

Segregation (Radioactive Waste)

An activity where waste or materials (Radioactive and Exempt) are separated or are kept separate according to radiological, chemical and/or physical properties which will facilitate waste handling and/or processing. It may be possible to segregate radioactive material from exempt material and thus reduce the waste volume.

Short-lived Waste

The radioactive waste in quantities and/or concentrations, which will decay to activity levels considered to be acceptably low from radiological point of view within the time period during which administrative controls are expected to last. Radionuclides in short-lived wastes will generally have half-lives shorter than 30 years.

Specification

A written statement of requirements to be satisfied by a product, a service, a material or process indicating the procedure by means of which it may be determined whether specified requirements are satisfied.

Spent Fuel

Irradiated fuel not intended for further use in reactors in its present form**.**

Storage (Waste)

The placement of radioactive waste in an appropriate facility with the intention of retrieving it in the future. Hence waste storage is by definition an interim measure and the term interim storage should not be used.

Surveillance

All planned activities viz., monitoring, verifying, checking including in-service inspection, functional testing, calibration and performance testing performed to ensure compliance with specifications established in a facility.

Technical Specifications for Operations

A document approved by the Regulatory Body covering the operational limits and conditions, surveillance and administrative control requirements for safe operation of the nuclear or radiation facility.

Waste, Alpha bearing

Waste containing one or more alpha emitting radinuclides, in quantities and/or concentrations above clearance levels.

Waste Form

The waste in its physical and chemical form after treatment and/or conditioning prior to packaging.

Waste Immobilisation

The conversion of radioactive waste into a solid form(by solidification, or by embedding or enscapsulating in a matrix material) to reduce the potential for migration or dispersion of radionuclides during transport, storage and disposal.

Waste Management

All administrative and operational activities involved in the handling, pre-treatment, treatment, conditioning, transportation, storage and disposal of radwaste.

Waste Package

The product of conditioning that includes the waste form and any containers and internal barriers (for example, absorbing materials and liners), as prepared in accordance with requirements for handling, transportation, storage and/or disposal.

Waste Treatment

Operation intended to benefit safety and/or economy by changing the characteristics of the wastes by employing methods such as:

(a) volume reduction

(b) removal of radionuclides

(c) change of composition

After treatment, the waste may or may not be immobilised to achieve an appropriate waste form.

CONTENTS

1. INTRODUCTION

1.1 General

1.1.1 The use of nuclear technology for the production of power inevitably results in the generation of radwaste which needs to be managed to ensure the protection of human beings and environment, without imposing significant constraints on future generations.

1.1.2 Radwastes arise in a variety of forms and wide range of radioactivity. Radwaste, as a source of ionising radiation, has been recognised as a potential hazard to human health. Certain basic principles of waste management have been developed in accordance with national and international regulations and standards dealing with radiation protection for safe disposal of the wastes.

1.2 Objective

The overall objective of this guide is to define the basic safety requirements for design and construction of the waste management facility in a manner that ensures protection of man and the environment. To achieve the same, this document highlights the overall design objective and an associated set of principles for the management of radwastes.

1.3 Scope

1.3.1 This guide applies to the management of liquid and solid radwaste generated during the operation. It also covers the discharge of liquid effluents into the environment, and disposal of solid/solidified/conditioned/unconditioned waste in engineered containment in Near Surface Disposal Facilities (NSDF).

1.3.2 This guide does not cover the following :

- requirements of the operational aspects of the waste management plant [1]
- waste arising from decommissioning [2]
- industrial chemical pollution.
- handling and disposal of alpha-bearing waste above the limits prescribed for NSDF
- enmasse replacement, like steam generators and heat exchangers

1.3.3 For management of gaseous waste and radiation protection, the relevant AERB safety guides may be referred to [3.4].

2. PRINCIPLES OF WASTE MANAGEMENT

2.1 General

The aim of waste management is to protect human beings and the environment, now, as well as in the future to ensure that radiation exposure is within prescribed/acceptable limits during all normal, off-normal and accident conditions. This is achieved by:

(i) minimisation of waste generation (by appropriate use of materials, methods, processes and management practices);

(ii) treatment of waste for removal of radioactivity before discharge/ disposal;

(iii) immobilisation of activity thus removed and isolation of immobilised activity.

2.2 Principles

2.2.1 Waste Management Philosophy

Waste management philosophy is based on the following principles:

(i) dilution and dispersal of low active waste;

(ii) delay/decay and disposal of waste containing short-lived radionuclides;

(iii) concentration and containment of high active waste.

3. STRATEGY FOR RADWASTE MANAGEMENT

3.1 General

The strategy adopted in the design of waste management plants should conform to the principles of waste management as far as practicable. The release of waste into the environment should be minimised, taking into consideration the economic and social factors. Occupational exposure to the operating personnel should be reduced to as low as reasonably achievable during operation, maintenance and in-service inspection.

3.2 Segregation

The waste should be segregated to make optimal use of treatment and conditioning methods.

3.3 Treatment and Conditioning

The treatment and conditioning methods should assure safe handling and disposal of waste. The waste may be reduced in volume in order to make the optimum use of storage, handling, transport and disposal methods. The waste may be conditioned or packed in a form to facilitate safe handling, transport, storage and disposal.

3.4 Waste Disposal

3.4.1 Solid Waste Disposal

NSDF should be provided at each nuclear power plant. Normally, the waste packages should be disposed off in the engineered barriers like earth trenches, RCC trenches, vaults, tile-holes and high integrity containers in an irretrievable manner. If required, certain wastes may have to be stored in a retrievable manner.

3.4.2 Liquid Waste Disposal

Release of radioactive liquid effluent into the environment shall be kept within the limits prescribed by AERB for a given site.

3.5 Waste from Unplanned Events

It is recognised that adequate built-in margins are normally available for normal and anticipated operational occurrences viz.,

- leakage of heavy water into process water due to failure of heat exchanger tube
- contamination of suppression pool water
- contamination of secondary system due to leak in steam generator tube
- leakage of moderator heavy water into calandria vault water

3.6 Institutional Control

An institutional control period of 300 years for the repository may be considered. This is mainly based on the 30 year half-life of Cs-137 present in the waste.

An active and passive institutional control for the desired period of isolation has to be planned by the licensee. A detailed plan of active and passive control with complete documentation of waste inventory at NSDF has to be worked out by the licensee and submitted to AERB for approval.

3.6.1 Active Control

Provisions should be made for preventive maintenance and regular inspection of access control barriers with post-operational surveillance programme. The institutional control of the facility under the active control period would be for a period of 100 years.

3.6.2 Passive Control

A passive control period of 200 years is envisaged after an active control period of 100 years. During this phase the facility would be provided with appropriate physical protection with the entry permitted only to authorised persons. Any surveillance or monitoring is not envisaged during the passive control period.

It is likely that the facility could be declared green and made available for public use after the expiry of total period of institutional control.

4. SAFETY REQUIREMENTS

4.1 General

4.1.1 All the radwaste management facilities should be designed in a manner directed to avoid unnecessary exposures and to keep unavoidable exposures as low as reasonably achievable (ALARA). The exposures in any case should be kept below the limits stipulated by AERB.

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4.1.2 Activity Build-up

Selection of material for equipment, pumps, pipelines etc., of waste management facility should be such as to ensure minimum activity build-up. The layout of pipes should be such as to avoid dead-legs and stagnant fluid which may give rise to 'hotspots'. Provision should be made for periodic decontamination and disposal of resultant wastes.

4.1.3 Radiation Monitoring

Trained personnel should be provided to carry out radiation monitoring programme for control of exposures, confinement of radiation sources, identification/analyses and radiation surveys. Adequate number of instruments including battery-powered portable instruments should be provided**.**

4.1.4 Environmental Monitoring

An environmental monitoring programme [3], suitably integrated with other facilities, should be carried out to:

(i) establish environmental indices which could be used to determine the impact, if any, on the environment due to discharge of radioactive effluents and disposal of solid wastes in NSDF;

(ii) demonstrate compliance with the discharge limits set by the competent authority;

(iii) determine radiation dose to the critical group.

5. DESIGN OF WASTE MANAGEMENT SYSTEM

5.1 General

The waste management system should aim at meeting the regulatory requirements with respect to the dose limits for plant personnel and public as per AERB stipulations. It should ensure system reliability, operability and availability.

5.1.1 Design Criteria

5.1.1.1 The radwaste management systems should be designed and constructed to comply with the AERB stipulations laid down in the authorisation for activity discharges from the plant to the environment.

5.1.1.2 The radiation exposures to the plant personnel and the public should be maintained ALARA, economic and social factors taken into account. The dose equivalent to individuals should not exceed the applicable dose limits set by AERB.

5.1.1.3 The design of the radwaste management systems, including selection of treatment and packaging methods, should ensure that the resultant waste form meets the requirements for transport, storage or disposal of waste.

5.1.1.4 The radwaste management systems should be so designed and constructed as to be separate from non-radioactive waste management systems at nuclear power plants.

5.1.1.5 The design of the radwaste management systems should identify and consider discrete event sequences, including operator error, which may give rise to significant risk.

5.1.1.6 The radwaste management system should be designed with sufficient capacity to enable storage and treatment of the waste generated during normal operation and anticipated operational occurrence. Equipment redundancy as appropriate to the process needs should be considered.

5.1.1.7 Due consideration should be given in the design of radwaste management system so as to facilitate decommissioning.

5.1.1.8 Although outside the scope of this guide, due consideration should be given in the design and operation of NPPs in minimising the generation of primary wastes.

5.1.2 Battery Limits

The battery limits for primary liquid radwaste collection system begin at the inlet nozzle of waste collection tank located at liquid effluent segregation system (LESS) area. Likewise, the battery limits for solid radwaste segregation system (SWSS) begin at the pre-designated points of collection of solid waste located in various areas of the plant.

The battery limits for liquid radwaste discharge system end at the discharge point of liquid waste to the environment, viz. the Main Out Fall(MOF). Likewise, the battery limit for solid radwaste disposal system ends at the point of disposal of packaged/conditioned solid waste at approved NSDF.

Typical functional divisions of waste management facility are shown in Figure-1.

5.2 Waste Categorisation and Classification

Wastes are categorised based on concentration of radionuclide/surface dose rate. This is useful for deciding segregation, transport, treatment, conditioning, shielding and disposal modes. For effective utilisation of treatment and conditioning process, wastes are also classified based on the source, physical and chemical forms. Some of the commonly encountered radionuclides of interest are given in Table-1.

5.2.1 Liquid Waste

5.2.1.1 Liquid Waste Categorisation

Liquid waste categorisation is done based on specific activity levels as indicated in Table-I.

This is also useful for the purpose of regulatory records.[5, 6].

TABLE-I : LIQUID WASTE CATEGORIES.

Category	Activity Level A (Bq/m^3) of gross β, γ	Remarks
I	$A \leq 3.7x10^4$	No treatment required.
II	$3.7x10^4 < A \leq 3.7x10^7$	Treatment may be required.
III	$3.7x10^7 < A \leq 3.7x10^9$	Shielding may be required; treatment required.
IV	$3.7x10^9 < A \leq 3.7x10^{14}$	Shielding, treatment and cooling necessary.
V	$3.7x10^{14} < A$	Shielding and cooling necessary.

Note: Normally Category IV and V liquid wastes are not encountered in PHWRs.

5.2.1.2 Liquid Waste Classification

Liquid wastes are classified based on radionuclide content, specific activity levels, type of radioactivity, ionic impurity levels, chemical nature, dissolved/ suspended solids, organic impurities like oil, grease, detergent waste, etc. Classification is mainly done to facilitate selection of processes and material of construction, etc. Typical liquid waste classification is given below in Table-II.

TABLE-II : LIQUID WASTE CLASSIFICATION

S.No.	Classification	Category	Sources
1	Potentially active waste	I	Showers, laundry.
2	Active non-chemical waste	I, II	Equipment and floor drains, decontamination rinses, laboratory rinses.
3	Active chemical waste	I,II,III	Active laboratory solutions, decon tamination solutions.
4	Tritiated waste	I,II	Heavy water upgrading plant reject, moderator room sump, drains from heavy water handling areas, etc.
5	Organic waste	I	Liquid scintillation solution, contaminated oil, grease, etc.

5.2.2 Solid Waste

5.2.2.1 Solid Waste Segregation

Solid wastes are segregated based on their physical forms, like dry or wet (sludges, slurries, ion exchange resins), their nature (pyrophoric, bio-degradable), compactable/non-compactable, radionuclide content/surface dose rate and conditioning and disposal requirements.

5.2.2.2 Solid Waste Categorisation

Solid wastes are categorised, based on surface dose rates [5, 6] as indicated below in Table-III. This is for suitable handling of solid waste and deciding the appropriate volume reduction/conditioning/disposal methods.

TABLE-III : SOLID WASTE CATEGORIES

Category	**Radiation dose rate D on the surface of waste - mGy/h**	**Remarks**
I	$D \leq 2$	Mainly ß-γ emitters, α - emitters insignificant.
II	$2 < D \leq 20$	
III	$20 < D$	

It is necessary to develop suitable methods to assess radio-chemical characterisation of long-lived radionuclides of the solid waste.

5.2.2.3 Solid Waste Classification

Solid wastes are classified based on their physical form, nature, radionuclide content, surface dose rate, etc. Classification is mainly done to facilitate selection of treatment processes, disposal requirements, etc. Typical classifications followed are indicated in Table-IV below.

TABLE-IV : SOLID WASTE CLASSIFICATIONS

S.No.	Classifications	Types
1	Combustible waste	Paper, wood, clothes.
2	Compactable waste insulation materials.	Paper, clothes, rubber, plastic and
3	Non-combustible waste	Metallic components.
4	Non-compactable waste	Building materials.
5	Wet waste	Sludges, concentrates
6	Spent resins and filters	Resins from PHT system, moderator system, end-sheilds cooling system, calendria vault cooling system and SFSB cooling system.

5.3 System Capacity and Redundancy

Safety and economic considerations govern the processing, storage capacity and component redundancy of the waste management system. These factors may directly affect availability of the waste treatment system, which in some cases may also affect availability of the nuclear power plant.

5.3.1 System Capacity

5.3.1.1 System Input

To design properly the system capacity of the individual waste treatment system, the waste design volumetric inputs and activity levels should be determined, both for normal operation and for anticipated operational occurrences. These data should be based on operational experience from similar reactor plants.

.5.3.1.2 Process Rate

System and component process rates are determined with reference to system input and storage capacity prior to processing.

In a liquid treatment system, for example, a large collection tank will allow the process equipment to be sized with excess capacity with respect to the expected input flow rate to reduce the processing time. This system should provide a capacity margin to cope with particular periods, such as plant outages and equipment outages.

5.3.2 Redundancy

Normally for safety consideration redundancy may not be required. However, in Pressurised Heavy Water Reactors (PHWRs) redundancy is provided in the following areas:

(i) transfer pumps in Liquid Effluent Segregation System (LESS);

(ii) transfer pumps in Treatment and Conditioning System (TCS); and

(iii) storage capacities for pre-treatment and post-treatment

Even if component redundancy is not required purely for safety reasons, it may be necessary to consider providing redundancy, keeping in mind the cost of providing vis-a-vis the cost of penalties associated with system downtime resulting from outages of equipment without backup.

Experience has shown that, as a minimum, the need for redundancy of waste processing sub-system/components involves the following factors:

(i) probability of component failure,

(ii) effect of failure on system performance,

(iii) ease of replacement or repair of components,

(iv) availability of alternative processing methods,

(v) availability of cross-connections with other systems,

(vi) cost of providing redundancy, and

(vii) cost associated with component outages.

5.4 Liquid Waste Management System

5.4.1 Liquid Waste Segregation System

5.4.1.1 Source and Segregation

Tritium is the major source of contamination in liquid waste streams, specific activity of which may vary depending upon its origin. The liquid waste streams arise from active floor-drains, reactor building sumps, decontamination centre, chemical laboratory, upgrading plant rejects, detergent waste from active laundry and drains from change room showers, etc. The laundry waste (detergent waste) should be segregated and handled separately, considering the process related problems with such wastes. The segregation is done mainly to facilitate the selection of proper treatment process and materials used. The present practice of segregation and nomenclature used for different categories of liquid waste streams is indicated in Table-2 : Estimated quantities and activity levels of liquid radwaste for 2x220 MWe PHWR and Table-3: Estimated quantities and activity levels of liquid radwaste for 2x500 MWe PHWR.

The segregation should be carried out as near as possible to the point of waste generation, i.e., at the source.

Liquid waste generation at the source is to be kept as low as reasonably practicable by adopting measures like avoiding reactor operations for prolonged period with failed fuel, by minimising the leaks from heavy water systems, in-service inspection, maintenance practices and proper zoning to minimise spread of contamination, etc.

All the waste streams should be properly segregated and collected to suit the process routes.

Separate tanks should be provided for each class of liquid waste stream. Adequate storage capacity equivalent to minimum of one day's arisings, for each class of waste, should be provided.

Segregated waste should be pumped to the respective large-capacity pre-treatment storage tanks located in dyke area for further treatment and disposal. All tanks with their piping and pumps should be at a centralised location with sampling provisions. Standby pumps should be provided to improve system availability. The volume of the dyke should be such as to accommodate the liquid corresponding to the full capacity of all the tanks located in the dyke.

5.4.1.2 Liquid Waste Transfer System

Liquid wastes are transferred from the place of generation to the treatment plant or from the treatment plant to the dilution and discharge point through pipelines [7]. Tankering mode may be adopted in exceptional cases.

(i) Waste Transfer Pipe Lines

. The following salient aspects should be taken into account :

- quality assurance during design, construction and operation stages
- volumetric measurements
- secondary containment (either in the form of pipes or water-proof RCC trench) in case of underground pipelines
- material compatibility
- corrosion protection
- in-service inspection and maintenance
- cleaning and decontamination
- detection of line failure and its management
- shielding
- provision of appropriate markers (for underground pipes) or fencing (if running above the ground)
- redundancy of lines
- isolation provisions
- instrumentation for flow and pressure measurement
- quick remedial measures in the event of failure

(ii) Liquid Waste Tankers

If relatively small quantities of low/intermediate level wastes are to be safely and economically transported, provision of a tanker between collection and receiving end may be considered. The following aspects should be taken into account:

- chemical nature of waste
- quality assurance during design, fabrication and operation of the tanker
- material compatibility
- volumetric measurements, levels, etc.
- shielding
- provision for collection of minor leaks
- provision for decontamination/periodic cleaning
- safe anchorage of containment vessel
- in-service inspection

5.4.2 Liquid Waste Treatment System

5.4.2.1 Process Selection

In selecting the most suitable and economic treatment methods for liquid wastes, consideration should be given to the following:

- quantity of waste involved
- activity content and radionuclide composition
- authorised discharge limits
- decontamination factors (DF)
- volume reduction factor (VRF)
- chemical composition, pH, etc.
- suspended/dissolved solid content
- simplicity, reliability and maintainability
- recycling possibilities
- exposures to personnel
- capital and operating costs

5.4.2.2 Considering the levels of activity encountered in liquid waste in PHWRs, normally, no treatment is required. However, simpler methods like filtration, dilution and dispersion may suffice. A typical scheme for radioactive liquid waste management is indicated in Figure-2. Different processes for treatment of liquid waste are available for use. Considerable judgement should be exercised before selecting a process or a combination of processes based on the above parameters. The major processes currently available are briefly described below:

(i) Filtration

This process can be adopted where activity is known to be associated with particulates in liquid medium. The technique is comparatively simple. The processes result in filter media as secondary waste. DF may vary from 2 to 5 depending upon the particulate load, associated activity and filtration efficiency. Filter media may be fixed in a cement matrix.

(ii) Chemical Treatment

For radioactive liquid waste containing total dissolved solids above 500 ppm, chemical treatment employing co-precipitation may be selected.

Overall DF of 10 or more, can be obtained in this process. The supernatant after filtration and dilution is discharged. Radionuclides get concentrated in the sludge which is fixed in a suitable matrix, like cement, for disposal as solid waste. Volume reduction factor expressed as the ratio of initial waste treated to sludge generated can be 50 to 500.

(iii) Ion-exchange

Wastes having total solids less than 1000 mg/l and free from surfactants, organic and chemical agents, etc., are suitable for treatment by this process. Ion-exchange process may be useful for volume reduction of high activity in the liquids containing low ionic impurities. Use of ion specific resins (e.g. hexacynocuproferrite forms of anion resin/resorcinol farnaldehyde weak acid type cation for Cs-137 removal) can be considered to achieve high volume reduction factors. Equipment is relatively simple and high volume reduction factors (200 to 10,000) and decontamination factor (DF) of 100 to

1000 can be obtained. Normally, regeneration of ion-exchange resin is not done to avoid generation of secondary waste. Small capacity mobile ion-exchange system may also be considered for certain applications.

(iv) Evaporation

This process is suitable for waste containing large salt concentrations, low level of suspended matter and requiring high DF. The waste should be free of explosives or thermally unstable ingredients, and detergents. Volume reduction depends on salt concentration in the solution. The process is sensitive to scaling, foaming, salt precipitation and corrosion. DF achievable range from 1000 to 10,000. Process like solar evaporation also can be employed for sites where climatic conditions are favourable, such as in Rajasthan Atomic Power Station (RAPS).

(v) Treatment of Organic Waste

Small quantities of contaminated oils and solution from liquid scintillation counters with low contamination levels are generated from operation of NPPs. These may be burnt and the gases released to the atmosphere in a controlled manner. Alternatively, these could be soaked in an absorbing media and disposed off in the earthern barrier or appropriate engineered barriers. These activities will be carried out as per approved procedures of the licensee.

5.4.3 Liquid Waste Storage

Storage should be provided for each category of untreated and treated liquid waste streams. Liquid waste tanks should be housed in RCC dyke. The dyke design should take into account the requirements for liquid hold-up capacity in the event of failure of the storage tank. In order to provide for any surge in waste volume generation due to anticipated operational occurrences, such as malfunction of equipment, frequent shutdowns and start-ups of reactor systems, etc., and for providing operational buffer, a waste storage capacity equivalent to minimum 10 days should be provided. However, this requirement need not apply to waste streams with low specific activity.

5.4.4 Liquid Waste Sampling

(i) Provision should be made to obtain representative samples of liquid radwaste at every stage of processing after homogenisation.

(ii) Sample lines should be as short as possible and routed to a common sample station, suitably located for the operator's convenience and designed to minimise exposure to the operator.

(iii) The sample line should be of suitable material compatible with the liquid being sampled and sized to maintain a turbulent flow. Sample return line as well as sample sink drain should be routed to an appropriate collection tank or active waste collection sump.

(iv) Continuous sampling provision at MOF after mixing of treated liquid waste with dilution water should be made to assure proper monitoring of liquid waste discharges to the environment. The sample take-off point should be at an appropriate location downstream of the point of injection of the liquid waste stream. Homogeneous mixing of the discharged waste with the dilution flow water may be established by dye studies. The sampling system design should be capable for round-the-clock continuous operation and have adequate sample volume collection provision to meet desired periodicity of sampling. Provision to recycle the sample tank contents to main discharge channel/header should be made. Provision should also exist to ensure that sample pump trips/stoppages do not go unnoticed.

5.4.5 Liquid Waste Discharge

(i) Provision should be made for monitoring liquid waste discharges on batch basis by necessary sampling and analyses, as specified in the Station Technical Specifications.

(ii) Provision should be made for controlling the liquid waste discharges. Necessary records should be maintained for relevant parameters like waste volume discharged, discharge rate, dilution water flow, radioactivity content (viz., gross beta, gamma and tritium) and pH.

(iii) Liquid waste discharge should be regulated in accordance with dilution water flow so that the technical specification limits are not exceeded.

(iv) Provision for collecting sample at MOF, after dilution, should be made to ensure that liquid waste discharges are kept within the authorised limits.

5.5 Solid Waste Management System

5.5.1 Solid Waste Segregation System

5.5.1.1 Source and Segregation System

Solid waste generated from the operation and maintenance of NPPs are mainly spent ion-exchange resins, air and liquid filters and contaminated materials. Spent resins, originating from the purification system, contribute to maximum radioactivity in the solid waste of all types.

Segregation of solid waste should be done based on its nature, surface dose rate, or source to suit available treatment, conditioning and segregation method. Segregation should be preferably carried out near the origin of waste, as far as practicable.

Adequate receptacles should be provided at different locations in the power plant for each category of waste to achieve the segregation. These locations/ segregation areas should have provisions for adequate shielding, material handling and vehicle access to ensure safe storage, handling and transportation of waste to the treatment and conditioning plant. Typical data on estimated quantities of primary and secondary solid radwaste for 2 x 220 MWe and 2 x 500 MWe are presented in Tables-4 to 7.

5.5.2 Transit Waste Storage

Adequate waste storage space should be provided for every stage of waste management viz., waste receipt, waste process and waste disposal. Minimum waste storage capacity, equivalent to seven days of waste arisings, should be provided at each stage. (Typical storage space may be of size 6m x 6m x 5m). In addition, the storage arising due to process-related requirement needs should also be considered for sizing of the storage area. Likewise, adequate storage facility for treated/conditioned waste should be provided at suitable location for interim storage during periods of non-availability of NSDF in the rainy season.

5.5.3 Waste Treatment System

5.5.3.1 Process Selections

In selecting the most suitable and economic treatment methods for solid waste, considerations should be given to the following:

- quality of waste
- surface dose rate and radionuclide compositions
- physico-chemical nature
- volume reduction factors
- acceptance criterion for solid waste product
- reliability and maintainability
- recycling possibilities
- capital and operating cost
- treatment of contaminated organic/oil waste

5.5.3.2 Processes

Due consideration should be given to the above parameters before selecting the process. Typical scheme for solid radwaste arrangement is shown in Figure-3. Different processes for treatment/conditioning of solid waste are explained below:

(i) Fragmentation

This is generally applicable to large objects or equipment parts with different degrees of contamination. The process indirectly reduces the volume by changing the shape of the waste. It facilitates storage of waste in containers and further processing by compaction or incineration.

(ii) Compaction

Low-level waste containing mostly compressible materials, such as paper, plastics, cotton, rubber, glass are subjected to this process. The extent of segregation determines the efficiency and safety of this process. Segregation should ensure that:

- explosive materials are excluded
- pyrophoric materials are absent
- waste should not contain any liquid as far as possible

Volume reduction factors vary from 1.5 to 5 depending on the applied pressure composition of the waste and degree of sorting/segregation. The range of applied pressure on the waste is generally between 40 to 100 kg/sq.cm. Provision should be made to avoid the spring-back action of compacted waste to get good volume reduction factor.

(iii) Incineration

This process is used for volume reduction of low-level solid wastes containing combustible materials. The basic properties of the waste affecting the incineration process include physical and chemical states and calorific value. With adequate segregation practices, this process can give volume reduction factor upto 50.

(iv) Waste Conditioning

In the context of solid waste the conditioning involves a process which converts the waste into a form possessing homogeneity in the waste matrix structure or into a form possessing lower leach rate, increased mechanical and/or chemical stability. The techniques used are encapsulation by metallic or non-metallic containment, embedment of waste in a medium such as cement or in thermosetting polymers. Spent resins sludges and spent filters are subjected to such processes prior to disposal.

The conditioning steps adopted should ensure the following:

- stability against chemical/biological/radiological degradation
- low solubility or leachability in ground water
- non-combustibility
- minimal practical volume
- ease of handling/transportation
- free from surface contamination
- durability of packing

5.5.4 Waste Packaging

All solid radwastes (primary and secondary) after conditioning or treatment or otherwise, should be packed before disposal. Dry solid wastes like contaminated components, activated charcoal filters, pre-filters, concrete chippings are suitably packaged prior to disposal. The packaging/conditioning method adopted should consider the following aspects:

- average and maximum surface dose rate of package/container
- total activity per package and contributing radionuclide
- type of matrix
- leach rate
- water content
- bulk density of waste package
- anti-corrosive measures for container
- gross weight and volume of package
- waste handling requirements

5.5.5 Waste Disposal

NSDF for each power station is co-located in its exclusion zone for avoiding long-distance transportation of waste. While designing the NSDF, following main considerations should be taken into account.

(i) Multiple barrier approach, to prevent migration of radioactivity to the environment, should be adopted. Barriers include matrix, backfill material, engineered barriers, earth trenches, RCC trenches/vaults, and tile holes/High Integrity Containers (HIC) and geo-environment of the disposal site.

(ii) The concentrations of radioactive materials which may be released to the environment in ground water, air, soil and vegetation should not result in an annual dose exceeding AERB stipulations.

(iii) The design of waste disposal system should be such as to minimise occupational exposure to the operating personnel.

5.5.5.1 Requirements of Multiple Barriers

(i) First barrier is the waste form, the selection of which should be done based on type of waste, radionuclide content and degree of isolation required.

(ii) Backfill materials like vermiculite, bentonite, black cotton soil filled inside and outside of the engineered barriers act as a secondary barrier. Need for back-fill material will be determined by the geo-environment of the NSDF.

(iii) Engineered barriers like earth trenches, RCC vaults/trenches, tile hole/ HIC serve as a third barrier against radionuclide migration.

(iv) Geo-environment of disposal site acts as a fourth and important barrier. It is desirable that the disposal site should have good sorption capacities for various radionuclides and low ground-water velocities.

5.5.5.2 Requirements of Engineered Barriers

(i) The packaged/conditioned waste should be disposed off in various engineered barriers, like earth trenches, RCC trenches/vaults and tile holes/HIC, based upon their dose rates and radionuclide content. Typical sketches of engineered barriers are shown in Figures 4 to 9.

(ii) Bottom of the engineered barriers, wherever practicable, should be above the normal water-table.

(iii) The engineered barriers should be waterproofed to avoid ingress of water.

(iv) All the engineered barriers should have dewatering and monitoring capabilities in the form of stand pipe.

(v) The engineered barriers should be suitably stabilised and sealed after the placement of waste packages. Top of the barrier should be waterproofed, followed by earth-fill and vegetation to reduce the surface dose rate as prescribed by AERB and to prevent erosion of the earth-fill.

5.5.5.3 General Requirements of NSDF

(i) Adequate area should be provided in NSDF for disposal of estimated quantity of waste arisings during plant life and during subsequent decommissioning needs.

(ii) NSDF area should be fenced and an adequate buffer zone provided between the fence and public utility.

(iii) Suitable material-handling facilities should be provided for handling and disposal of waste packages.

(iv) The facility should have access roads to suit easy movement of different types of vehicles used for waste transportation.

(v) Area around the disposal facility should have an adequate number of bore-holes for monitoring to ensure integrity of disposal site. Location, numbers and depth of bore-holes should be decided, based on the geo-hydrological studies conducted at that site.

(vi) The disposal site should be generally well drained and free of areas of flooding or frequent ponding. Upstream drainage areas must be minimised to decrease the amount of run-off which could erode or inundate waste disposal units.

5.5.5.4 Safety Evaluation

The safety evaluation of NSDF should be carried out with due consideration to the following:

- total site burden viz., total activity that can be disposed off in the NSDF during the entire operating life of the NPP
- waste package characteristics
- engineered containment system
- physico-chemical properties of the soil
- geo-hydrological characteristics of site

The radiation dose to the population, assessed from an analytical model of radionuclide migration, based on the multiple barrier approach, should be within the dose limits prescribed by AERB.

5.6 Equipment and Materials

5.6.1 General Requirements and Recommendations

Safety classification and seismic categorisation shall be carried out as per relevant AERB Safety Guide [8].

5.6.1.1 Limiting Operating Conditions

The equipment design should consider limiting operating conditions, e.g., pressure, temperature, waste composition and flow rates during normal operation and anticipated operational occurrences.

5.6.1.2 Design Codes

The equipment material selection, design, fabrication, inspection and testing should comply with the respective appropriate design codes. Table-8 gives codes applicable for equipment like pressure vessels, storage tanks, heat exchangers, pumps and piping.

5.6.1.3 Inspection

Manholes and inspection holes should be provided on the components which require accessibility.

5.6.1.4 Flushing

Connections should also be made for flushing components and piping that will contain slurries, e.g., ion-exchange resins and concentrates. Some components may also include internal flushing devices.

5.6.1.5 Testing

The design should include provision for testing of system leak-tightness.

5.6.1.6 Material Selection

The material selected should be compatible with regard to the operational conditions, mechanical, thermal and chemical aspects. Radiation and decontamination effects on materials should also be taken into consideration.

5.6.1.7 Identification

Components should be identified by the plant identification code with a name-plate showing the code. Piping should be identified by colour codes, according to the fluid transported.

5.6.1.8 System Internals

Provisions should be made for loading or unloading of system internals and/ or process media, e.g., filters, ion-exchange resins, etc. The design should facilitate safe handling and minimise personnel exposures.

5.6.1.9 Vents

Waste treatment systems should have provision for venting.

5.6.1.10 Drains

Waste treatment systems should have provision for draining of liquids. Drain lines should be located at the lowest point to allow as complete drainage as possible.

5.6.2 Equipment for Liquid Waste Management System

5.6.2.1 Tanks

(i) Atmospheric storage tanks should be provided with vents sized to prevent tank over pressure or vacuum conditions.

(ii) Tanks should be provided with overflows routed to nearby floor-drains or other suitable collection point connected to an active sump.

(iii) Vent and overflow piping should not interfere with normal maintenance.

(iv) Potential leaks from tanks containing radioactive materials should be collected in suitable way and returned to liquid waste treatment system.

(v) Tanks should be placed in leak-tight dykes in order to contain the liquid contents of the tank in the event of tank/equipment pipe failure.

(vi) Tank design should preclude crevices and pockets. Provision should exist for its cleaning and decontamination.

vii) Provision should be made for mixing of tank contents to obtain a representative sample.

5.6.2.2 Pumps

Pumps should be equipped with reliable seals commensurate to the fluid characteristics and radioactivity. Where slurries or highly concentrated solutions are to be pumped, seal water should be provided to flush the seal.

5.6.2.3 Valves

Diaphragm or bellow-sealed valves may be used to minimise leakage from the system containing radioactive liquids. Slurry valves should be full ported, e.g., plug or ball valves or diaphragm-type.

5.6.2.4 Evaporators

(i) Type Selection

Thermosyphon or pot type evaporators are normally selected for evaporation of liquid waste.

(ii) Material Selection

Materials should be selected and provided with sufficient corrosion allowances, to withstand the boiling conditions of the concentrated solutions, with consideration for impurities which may be present and for chemical adjustment of the evaporator feed.

(iii) Maintenance

In evaporators, tube bundles or the entire heater should be removable.

(iv) Decontamination

Connections should be provided for the addition of cleaning chemicals for decontamination and scale removal.

5.6.2.5 Sumps

(i) It is desirable that sumps collecting radioactive liquid should be lined with either stainless steel (SS) or carbon steel painted with epoxy, depending upon the chemical nature of the liquid.

(ii) Sumps should be provided with instrumentation for automatic starting and stopping of the sump pump. Monitoring of sump level and pump operation should also be included.

5.6.2.6 Ion-exchangers

(i) Resins should be added from an accessible area hydraulically, with or without aid of air, or by gravity.

(ii) The spent resin should be removed from the ion-exchange column hydraulically into a disposable vessel of equal capacity.

(iii) In case of disposable ion-exchange column, appropriate provision should be made for its easy removal, dewatering, handling and closure of opening.

(iv) Resin traps should be installed to trap resins in the event of failure of the internal screen or resin support device. The traps should be provided with back-flush facility.

5.6.2.7 Filters

(i) Filter vessels should be provided with vent and drain connections and designed to allow complete drainage. Vent piping and connections should not interfere with remote disassembly of filters.

(ii) Filter housing and internals should be designed so that exposures of site personnel during the removal of spent filter cartridges will be minimum.

5.6.2.8 Sludge Blanket Clarifier

Sludge blanket clarifier should be provided with sludge outlet connections for periodic sludge removal. The clarifier should be provided with drain connection.

5.6.3 Equipment for Solid Waste Management System

5.6.3.1 Compactor

Pre-shredding of waste may be done to increase efficiency of the compactor. Compactor should include the following:

(i) A mechanism to hold container in position for the ram.

(ii) An exhaust system to prevent release of airborne particulates during the compression operation. It should be exhausted through a HEPA filter, or be connected to the building ventilation system.

(iii) Provision to collect liquids squeezed out during compaction should be made.

(iv) It is recommended to have anti-spring-back device to hold the compacted waste in place.

5.6.3.2 Incinerators

If an incinerator system is to be used, the following requirements should be met:

(i) Selection of incinerator type and design of off-gas treatment system should take into consideration the physical, chemical and radiological characteristics of combustible waste and combustion products.

(ii) Consideration should be given to provision for venting pressure surges directly to the stack.

(iii) It should be ensured that negative pressure is maintained within the boundary of the entire system upto the induced draft fan during operation.

(iv) The off-gas treatment system should be capable of adequate retention of particulates, chemical contaminants, and radioactive isotopes to ensure that the discharge to atmosphere is in conformity with all applicable regulations, for radioactive as well as non-radioactive releases, during normal operation and during anticipated operational occurrences.

(v) If heat exchangers are used, the design should take care, the needs of periodic cleaning.

(vi) Negative pressure should be reliably maintained in the ash container or the enclosures during ash removal and cool-down to prevent ash from escaping into air.

5.6.3.3 Equipment/Systems for Solidification

The solidification system should include equipment for storage, metering, filling, mixing of waste and solidifying agent and interim storage arrangement for conditioned waste. Following considerations should be given while designing these systems:

(i) Storage

The bulk storage capacity for solidifying agents should be large enough to receive bulk shipment plus sufficient reserve to permit continued operation. Provision for storage of solidifying agents like polymer, accelerator and catalyst at recommended temperature should be made. Care should be taken to store these chemicals separately. Appropriate safety features should be provided to protect the operating personnel from chemical hazards.

(ii) Filling

Filling of the solidification agent, additives or catalyst feed tank should be from a non-contaminated, low radiation area with normal precautions taken for the material involved. If cement or other powdered material is the solidification agent, the feed tank should have a dust collection system including a filter to remove dust.

iii) Metering

Metering of solidification agents, additives or catalyst should have the accuracy and range necessary to achieve the desired product quality. Powdered-type solidification agents should be weighed for better accuracy.

5.6.3.4 Waste Metering and Mixing

The mixing of wet waste with the solidification agent should occur in a mixer just prior to filling a container or alternatively in the container.

(i) Metering

Metering of wet waste should have the accuracy and range necessary to achieve the desired product quality.

(ii) Homogeneous Mixture

The design of the mixing system should ensure that the waste is uniformly distributed throughout the matrix. Homogeneity should be demonstrated by visual or other appropriate means during the pre-operational tests.

(iii) Cement mixer Considerations

The mixer should have flexibility to accommodate the various cement/waste ratios and be designed to minimize the volume of waste remaining in the mixe, after use.

(iv) Flushing

In systems that mix outside the container the length of the pipe between the mixing and filling should be as short as possible to minimise system flushing quantities.

5.6.3.5 Embedment of Dry Waste

Spent liquid filters are normally received alongwith their housing. Provision for draining water from the filter housing and subsequent addition of cement grout to the filter housing should be made.

5.7 Safety Classification and Seismic Categorisation [8]

5.7.1 The design of civil structures of the waste management system should be as per AERB safety guide on “Safety Classification and Seismic Categorisation of Structures, Systems and Components”. The following Table-V indicates safety classification and seismic categorisation of some important systems.

TABLE-V : SAFETY CLASSIFICATION AND SEISMIC CATEGORISATION OF SYSTEMS

Systems/Area	Safety classification	Seismic category
Spent resin processing area	3	II
Dyke area	4	II
Liquid and solid waste treatment and conditioning, process building	4	II
Near surface disposal	4	III
Utilities and services	4	III

5.7.2 Safety classification for electrical, instrumentation equipment and components should be Class 4, EC, and IC respectively. Safety classification for mechanical equipment/components should be Class-4. Seismic category for mechanical, electrical and instrumentation equipment and components should be Category-III.

5.8 Physical Arrangements

5.8.1 General Arrangement/Layout

The equipment and components of the waste management system should be located, arranged and shielded to minimise radiation exposure to the site personnel during operation and maintenance. The system and equipment design and arrangements should limit the need for personnel to enter high radiation areas to perform maintenance, inspection or testing.

5.8.2 Building and General Layout

The building structure and the general system layout should be arranged such that gross leakage from any piping system or equipment is confined to the local area. The layout should give consideration to segregating equipment containing high radioactive materials.

5.8.3 Access

Piping, tubing, conduit and valves extension handles from tanks or equipment should not hinder personnel and materials movement.

5.8.4 Pump, Valve and Instrumentation Location

Pumps associated with tanks or process equipment containing radioactive materials should be located outside the shielded area in which the tank or process equipment is located. The same recommendation applies to process valves frequently operated and/or maintained.

Instrumentation, control panels, valves, chemical addition points, etc., should be located, as far as practicable, outside of the process equipment enclosures.

5.8.5 Shield Penetration

Penetration of shielding walls by pipes and ducts should be designed to minimise personnel exposure, apart from other design considerations, such as fire-barriers, ventilation air flow etc.

5.8.6 Pipe runs

Process sub-system should be arranged to minimise tees, elbows, dead legs and the length of piping runs to minimise the number of points in the piping where radioactive sediment can collect. Formation of unintended siphons should be prevented.

Due care should be taken to ensure that radioactive process fluids do not contaminate the utility lines due to back-flow because of any maloperating conditions.

Process lines carrying resins, sludges and evaporator concentrates should be provided with arrangements for flushing.

5.8.7 Contamination Control

Process equipment, tanks, filters, evaporators and ion-exchangers should be located so as to minimise the spread of contamination and facilitate decontamination, should spillage occur. Typical measures include provision of adequate ventilation, drainage system, curbing and surface finishes for facilitating decontamination of floors and walls.

5.8.8 Ventilation

Ventilation air supply and exhaust to and from different areas of the facility should be designed to meet the requirements of health and safety. The design should consider factors like number of air changes per hour, zoning philosophy and human comfort. The ventilation exhaust should be filtered using HEPA filters to remove particulate radioactivity before release to the atmosphere.

5.8.9 Shielding

Shielding calculations should be based upon the maximum radioactivity levels and estimated contamination build-up. Consideration should be given to the possibility that systems not containing fluids during normal operation may carry radioactive fluids under anticipated operational occurrences.

The shielding and arrangement of equipment and components handling radioactive waste should be a function of the degree of access required for operation, inspection, testing and maintenance.

Component separation by distance or shielding or both should be utilised to minimise exposure to operating personnel.

5.8.10 Material handling

Material handling, lifting and remote operating facilities should be considered wherever necessary to facilitate equipment/component removal/replacement for maintenance or to minimise radiation exposure to the plant personnel.

5.8.11 Fire Protection

Fire protection should be provided as per relevant AERB safety guide [9]. Provisions may be made, based upon evaluation of fire hazard potential of different areas of the plant. Adequate instrumentation for the fire protection system should be provided.

5.8.12 Lighting

The plant areas should have adequate lighting for normal operation and maintenance of the system. Emergency lighting and indication of escape routes should also be provided in all operating areas.

5.8.13 Electrical Power Supply

Since waste management processes are batch processes, power supply to the equipment could be of Class IV.

5.8.14 Utilities and Services

Equipment/components for systems like air compressor, ventilation, air supply, electrical transformer and switchgears, boiler and process water should be located separately in inactive areas.

5.9 Quality Assurance

A quality assurance programme for radwaste management systems should be established and documented to ensure that applicable specified requirements are followed. The programme should be a part of the overall quality assurance programme for the NPP [10].

6. INSTRUMENTATION AND CONTROLS

6.1 General

Instrumentation and control system should include various sensing elements, remote control switches, status indicators for equipment and valves, other process information instruments and automatic controls necessary to ensure safe and reliable operation.

6.1.1 The instrumentation should provide indication and/or recording of parameters necessary to monitor and control the system and its equipment.

6.1.2 The measuring range of the instrumentation should cover the system variations under normal conditions and anticipated operational occurrences.

6.1.3 The instrumentation should also give alarm of, and/or indicate, abnormal or undesirable conditions which could adversely affect release from the system/ equipment performance.

6.2 Process Instrumentation and Control

Instrumentation and controls should be provided to measure, record, indicate, monitor and control various process parameters of the treatment system.

6.2.1 Instrumentation

Typical process parameters requiring measurements and controls are as follows :

- level for all storage tanks and sumps
- pressure and flow (on process lines)
- differential pressure for ion-exchange column, filters, in-line mixer, etc.
- temperature (for evaporator and polymerisation system)
- weight of batching for cementation, polymerisation, etc.
- pH

- conductivity
- on-line activity in the discharge line

6.2.2 Controls

6.2.2.1 Remote Controls

In order to minimise personnel exposure and allow a better display of the status of the system, remote control switches should be provided for frequently actuated valves and components.

6.2.2.2 Interlocks

To ensure proper operation and protection of components, and to minimise operator errors, the control system should be provided with necessary interlocks.

6.2.2.3 Manual Overrides

Provided, safety is not affected where automatic control is provided, manual override capability should be available to maintain system operability during a fault sequence.

6.3 Remote Viewing

Remote viewing provisions should be included in the design where radiation protection considerations preclude direct viewing of operations, e.g., mixing, packaging, capping and container handling.

6.4 Control Room Requirements

Instrumentation and controls should be provided to allow operation of a system from a control room, with following essential information displayed in the main control room. In case of LESS (if located away from the waste management plant), all controls and tank levels should be provided in the main control panel.

Following information should be provided in the control room:

- all tanks/sump level indications with alarm functions

- waste storage tank-level
- waste receipt and treated waste discharge flow
- treatment flow indications
- pumps and automated valves on/off status
- area monitors alarms
- pump/valve operation
- ventilation system status

6.5 Local Control Panel

Local control panels should be provided wherever necessary for specific process requirements, e.g., for resin transfer, resin polymerisation, volume reduction and solidification system, etc.

6.6 Communications

Communication should be provided between major operating locations as well as the main control room.

TABLE-1 : RADIONUCLIDES OF INTEREST

Radionuclide	Half-life	Radioactive emission
H-3	12.5y	β
P-32	14.3d	β
S-35	87.4d	β
Ca-45	163d	β
Cr-51	27.7d	EC, β
Mn-54	312d	EC, β
Fe-59	44.6d	β
Co-58	70d	β, EC
Co-60	5.2y	β,γ
Ni-63	96 y	β
Zn-65	243d	β, EC
Sr-90	30y	β
Nb-95	35d	β,γ
Zr-95	64d	β,γ
Ru-103	40d	β,γ
Ru-106	368d	β,γ
Sn-119	293d	IT
Sb-124	60d	β
Sb-125	2.77y	β,γ
I-131	8d	β,γ
Cs-134	2.062y	β, γ
Cs-137	30y	β,γ
Ba-140	13d	β,γ
Ce-141	32.5d	β,γ
Ce-144	284d	β,γ

EC- Electron capture IT- Isomeric transition

TABLE-2 : ESTIMATED QUANTITIES AND ACTIVITY LEVELS OF LIQUID RADWASTE FOR TYPICAL 2x220 MWe PHWR

Sl. No.	Waste Stream	Quantity (m^3/d)	Activity levels(Bq/ml)		Remarks
			Gross beta (GB)	Tritium (H^3)	
1	Potentially Active Waste (PAW)				
	a) Showers	18	3.7E-3	1.85E+1	
	b) Washrooms	12	3.7E-2	1.85E+1	
	c) Laundry	20	3.7E-1	3.70E+1	
2	Active Non-Chemical Waste (ANCW)				
	a) ANCW I	25	1.85	3.7E+2	
	b) ANCW II (Tritium rich)	10	1.85	3.7E+3	
3	Tritiated Waste (TTW)				
	a) Reactor Building Sump	01	1.8	1.1E+5	
	b) D_2O Upgrading Plant	03	3.7E+1	7.4E+4	
4	Active Chemical Waste (ACW) Decontamination waste (primary)	0.5 m^3/week	1.85E+3	1.85E+4	Occasional
5	Organic waste	10 (l/d)	3.7E-2	1.85E+3	Occasional

TABLE-3 : ESTIMATED QUANTITIES AND ACTIVITY LEVELS OF LIQUID RADWASTE FOR TYPICAL 2x500 MWe PHWR

Sl. No.	Waste Stream	Quantity (m^3/d)	Activity levels(Bq/ml)		Remarks
			Gross beta (GB)	Tritium (H^3)	
1	Potentially Active Waste (PAW)				
	a) Showers	36	3.7E-3	1.85E+1	
	b) Washrooms	24	3.7E-2	1.85E+1	
	c) Laundry	30	0.37	3.70E+1	
2	Active Non-Chemical Waste(ANCW)				
	a) ANCW I	45	1.85	3.7E+2	
	b) ANCW II (Tritium rich)	20	1.85	3.7E+3	
3	Tritiated Waste (TTW)				
	a) Moderator Room Sump	02	1.85	1.1E+5	
	b) D_2O Upgrading Plant	06	3.70E+1	7.4E+4	
4	Active Chemical Waste (ACW) Decontamination waste (primary)	01 (m^3/week)	1.85	1.85E+4	Occasional
5	Organic waste	20(l/d)	3.7E-2	1.85E+3	Occasional

TABLE-4 : ESTIMATED QUANTITIES OF PRIMARY SOLID RADWASTE FOR TYPICAL 2x220 MWe PHWR

Sl. No.	Type of Waste	Average quantity (m^3/y)	Surface dose rate (mGy/h)	Remarks
1	Combustible waste	100	< 2	-
2	Non-combustible waste	10	< 2	-
3	Non-compactable waste	50	1 to 100	Occasionally dose rate up to 500 mGy/h
4	Spent liquid filters	9	200 to 4000	-
5	Spent IX resins a) Moderator b) PHT c) End shield d) Calandria vault cooling system e) SFSB	 12 3 1 1 3	 <100 <5000 <10 <10 <500	 - - - - -
6	Highly active reactor components	0.1	20 to 500	-
7	HEPA filters	3	0.001 to 0.1	Generated during replacement
8	Miscellaneous	2	< 0.3	-
9	Total	193.1		-

TABLE-5 : ESTIMATED QUANTITIES OF PRIMARY SOLID RADWASTE FOR TYPICAL 2x500 MWe PHWR

Sl. No.	Type of Waste	Average quantity (m^3/y)	Surface dose rate (mGy/h)	Remarks
1	Combustible waste	140	< 2	-
2	Non-combustible waste	20	<2	-
3	Non-compactable waste	70	1 to 100	Occasionally dose rate upto 500 mGy/h
4	Spent liquid filters	15	200 to 4000	-
5	Spent IX Resins a) Moderator b) PHT c) End shield cooling system d) Calandria vault cooling system d) PHT e) SFSB	 27 6 1 1 6	 <100 <5000 <10 <500 <10 <500	 - - - - - -
6	Highly active reactor component waste	0.2	20 to 500	-
7	HEPA filters	5	0.001 to 0.1	Generated during replacement
8	Miscellaneous	3	<0.3	-
9	Total	302.2		

TABLE-6 : ESTIMATED QUANTITIES OF SECONDARY SOLID RADWASTE FOR TYPICAL 2x220 MWe PHWR

Sl. No	Type of Waste	Average quantity (m^3/y)	Surface dose rate (mGy/h)
1	Spent HEPA filters	2	<2
2	Spent Liquid filters	10	0.2 to 20
3	Spent IX resins	0.5	>20
4	Combustible waste	10	<2
5	Miscellaneous	2	<2
6	Total	24.5	

TABLE-7 : ESTIMATED QUANTITIES OF SECONDARY SOLID RADWASTE FOR TYPICAL 2x500 MWe PHWR

Sl. No	Type of Waste	Average quantity (m^3/y)	Surface dose rate (mGy/h)
1	Spent HEPA filters	2	<2
2	Spent Liquid filters	10	0.2 to 20
3	Spent IX resins	1	>20
4	Combustible waste	10	<2
5	Miscellaneous	2.5	<2
6	Total	25.5	

TABLE-8 : EQUIPMENT DESIGN CODES

Sl. No.	Equipment	Design and manufacture Code/ Standard	Materials [1,2,3]	Welder qualification and procedure	Inspection and testing	Safety classifi-cation
1	Pressure vessels	ASME Section -VIII	ASME Section-II IS: 2062/2002	ASME Section-IX	ASME Section - VIII	IV
2	Storage tanks with conical roof and flat bottom	IS-803	As applicable by code	ASME Section-IX	IS-803	IV
3	Storage tanks with dished ends	IS-2825 ASME Section -VIII	ASME Section-II IS: 2062/2002	ASME code Section-IX	IS-2825 ASME Section -VIII	IV
4	Heat exchangers	ASME Section-VIII and TEMA	ASME Section-II	ASME Section-IX	ASME Section-VII	IV
5	Piping and valves	ANSI B31.1 ANSI B 16.34	ASME Section-II ASTM	ASME Section-IX	ANSI B31.1 or MSSP ANSI : B16.34 IS : 5120	IV
6	Pumps	Manufac-turer's Standard	ASME Section-II or manufac-turer's standard	ASME Section-IX	Hydraulic Institute Standard	

Note : 1. Material manufacturer's certified test reports should be obtained wherever possible.
2. Malleable, wrought or cast iron normally should not be used.
3. Materials for tools, pipes, sumps and process equipment should be compatible with fluid handled.

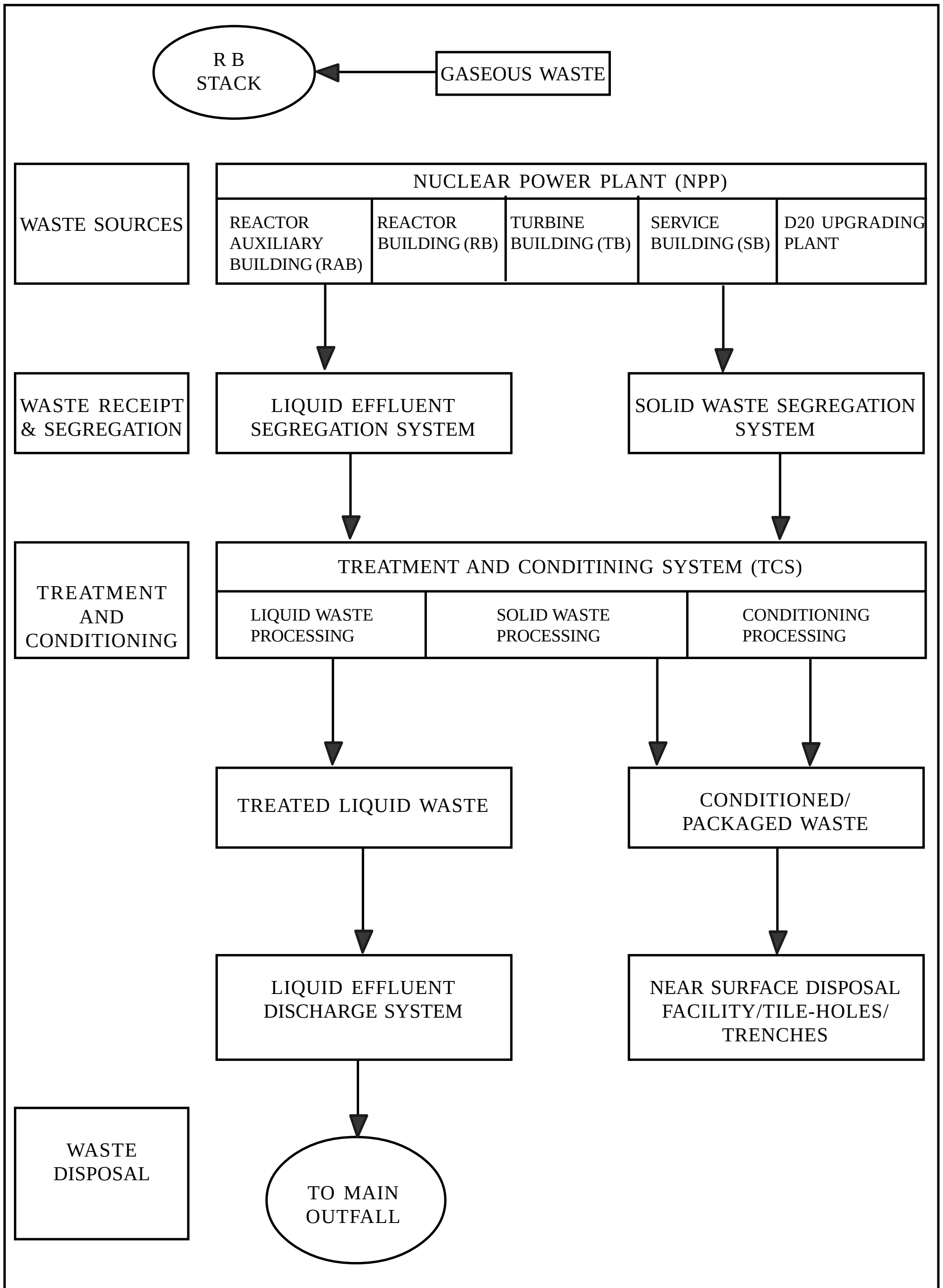


FIG. 1 : TYPICAL FUNCTIONAL DIVISIONS OF WASTE MANAGEMENT FACILITY

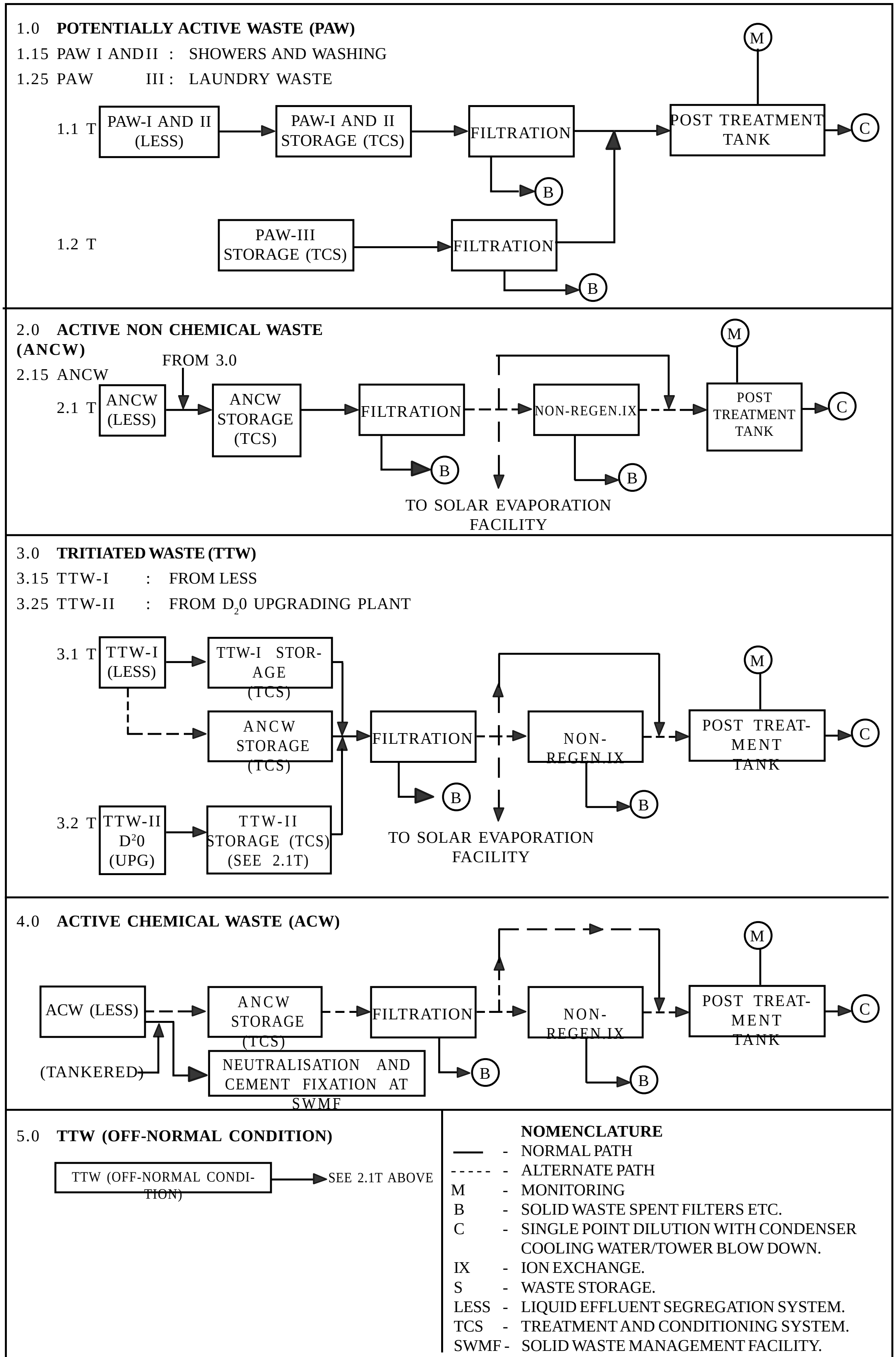


FIG. 2 : TYPICAL SCHEME FOR LIQUID RADWASTE MANAGEMENT

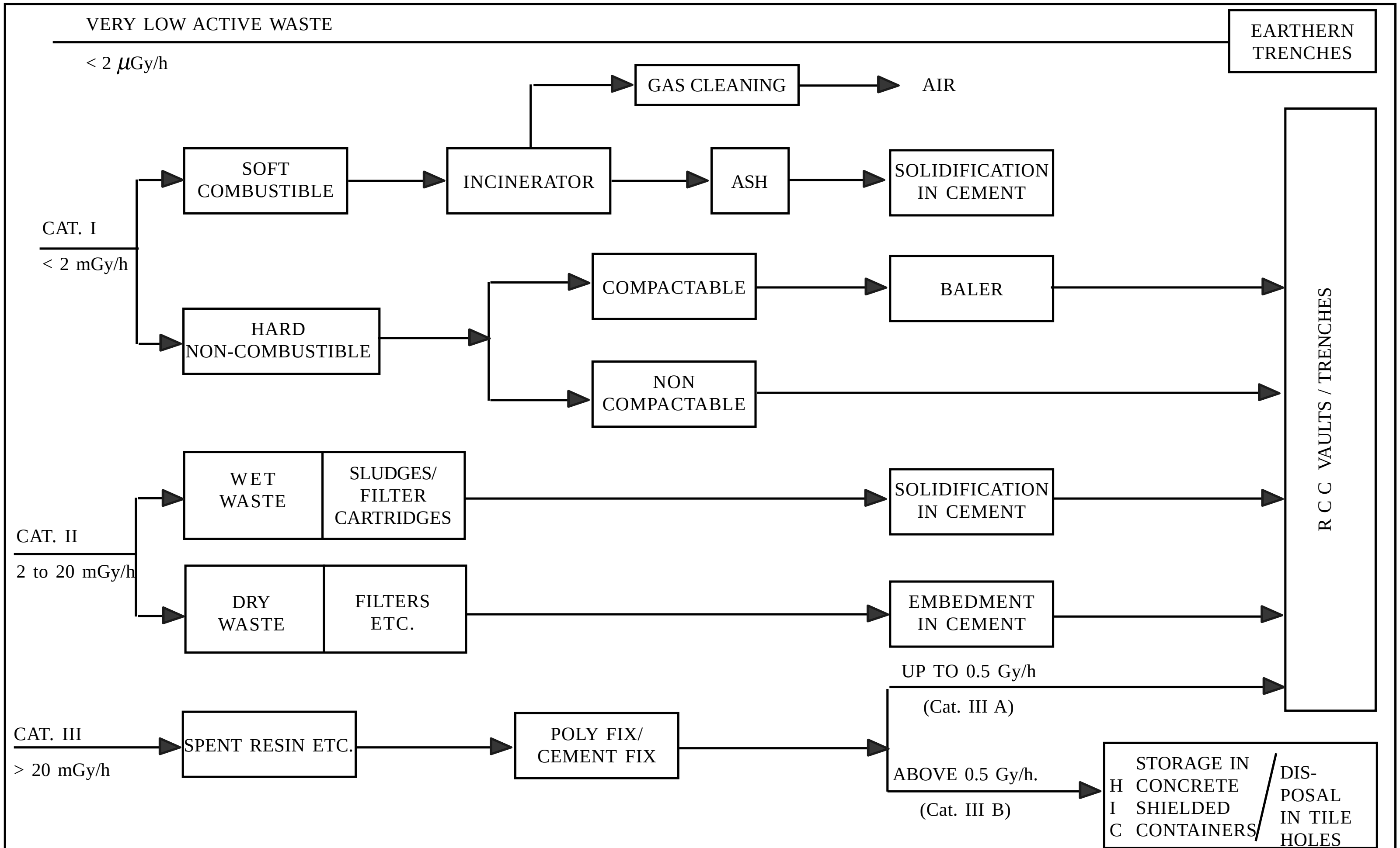
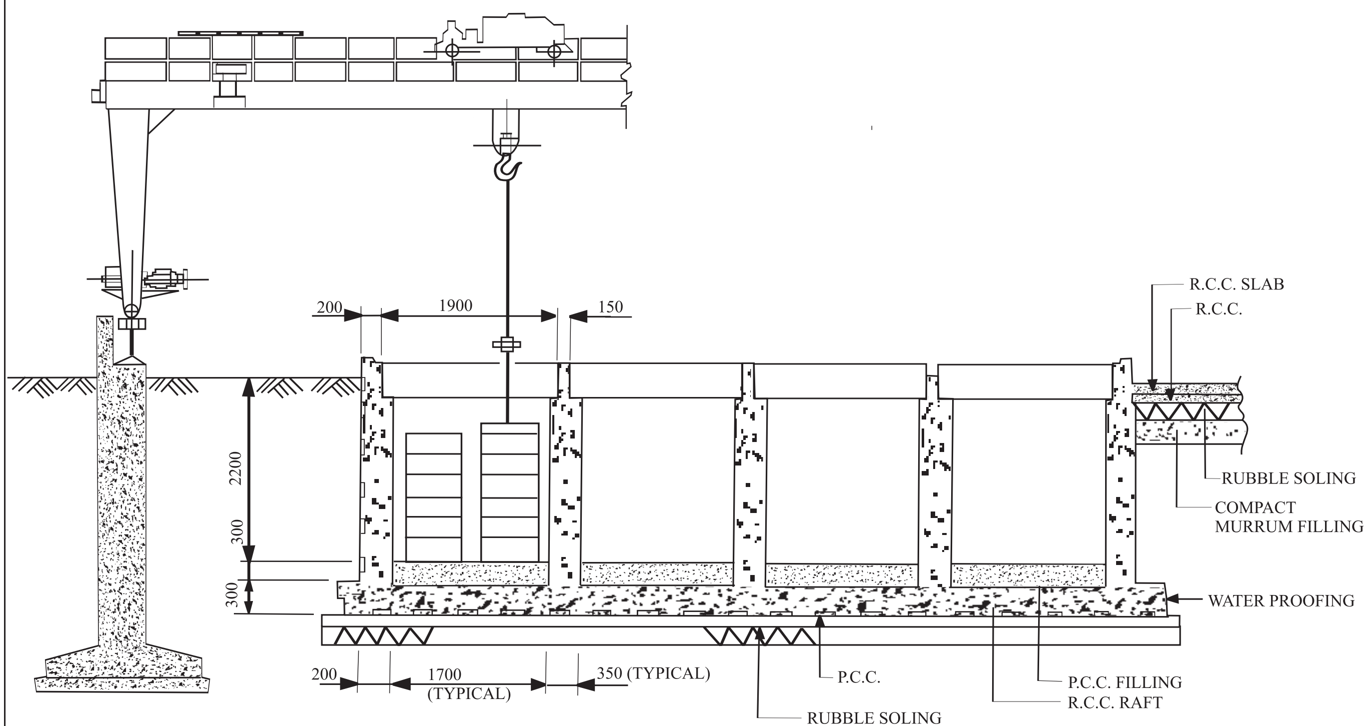
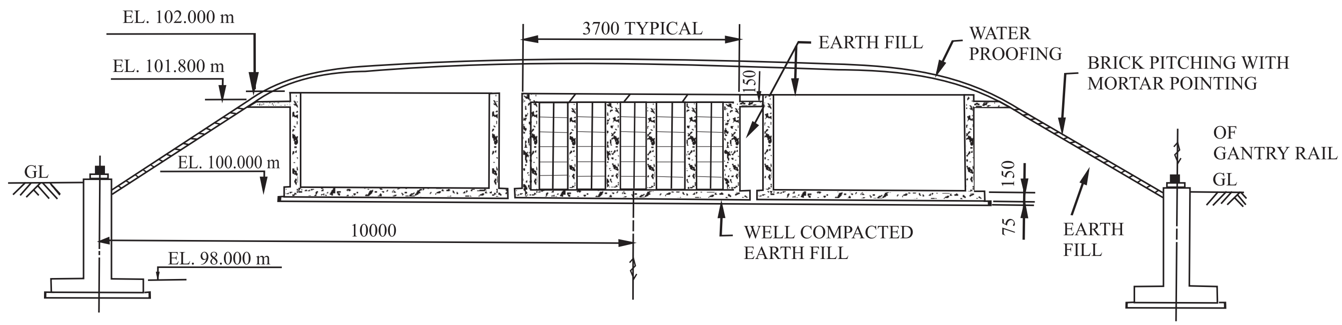


FIG. 3 : TYPICAL SCHEME FOR SOLID RADWASTE FACILITY



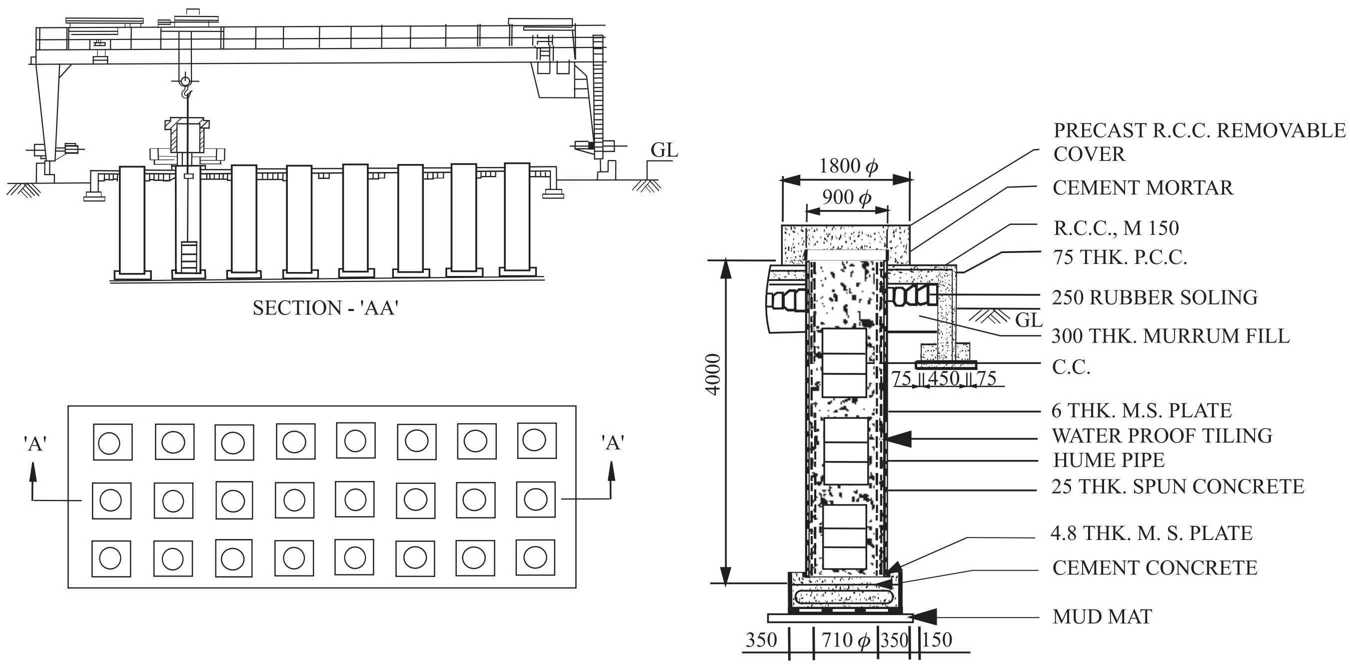
NOTE : ALL DIMENSIONS ARE IN mm UNLESS SPECIFIED

FIG. 4 : TYPICAL CROSS-SECTION OF REINFORCED CEMENT CONCRETE TRENCH



NOTE : ALL DIMENSIONS ARE IN mm UNLESS SPECIFIED

FIG. 5 : TYPICAL DETAILS OF REINFORCED CEMENT CONCRETE STORAGE VAULT



NOTE 1. P.C.C. - PLAIN CEMENT CONCRETE
2. THK. - THICK
3. ALL DIMENSIONS ARE IN mm UNLESS SPECIFIED

FIG. 6 : TYPICAL TILE-HOLES LAYOUT AND CROSS-SECTION

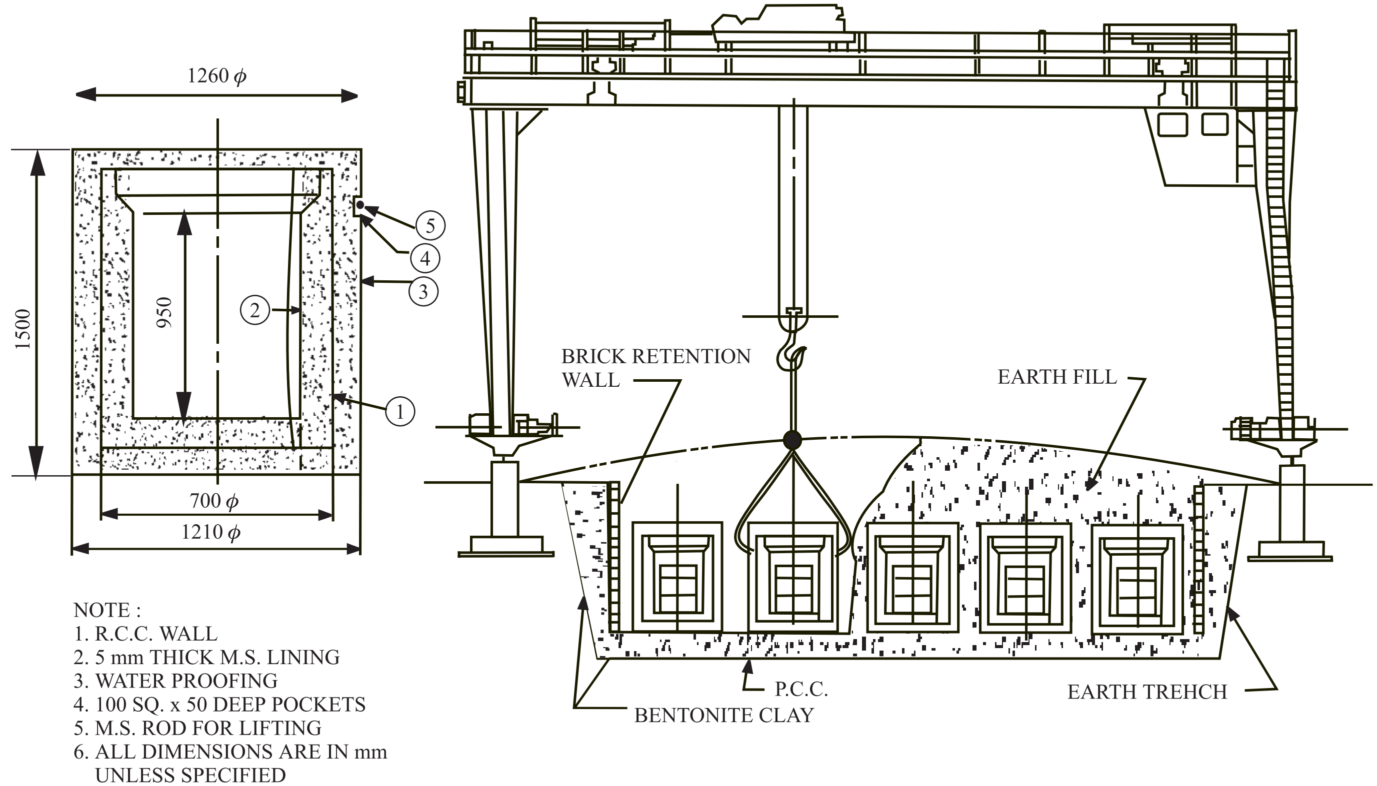
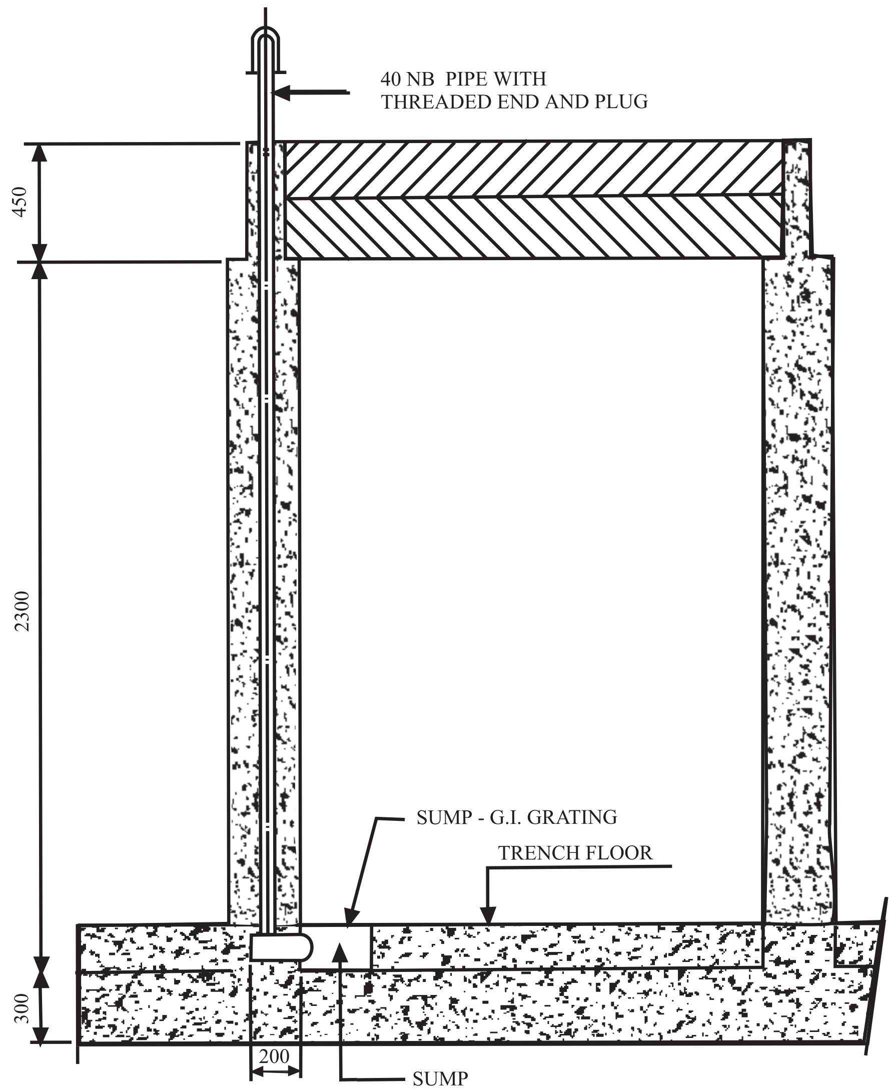
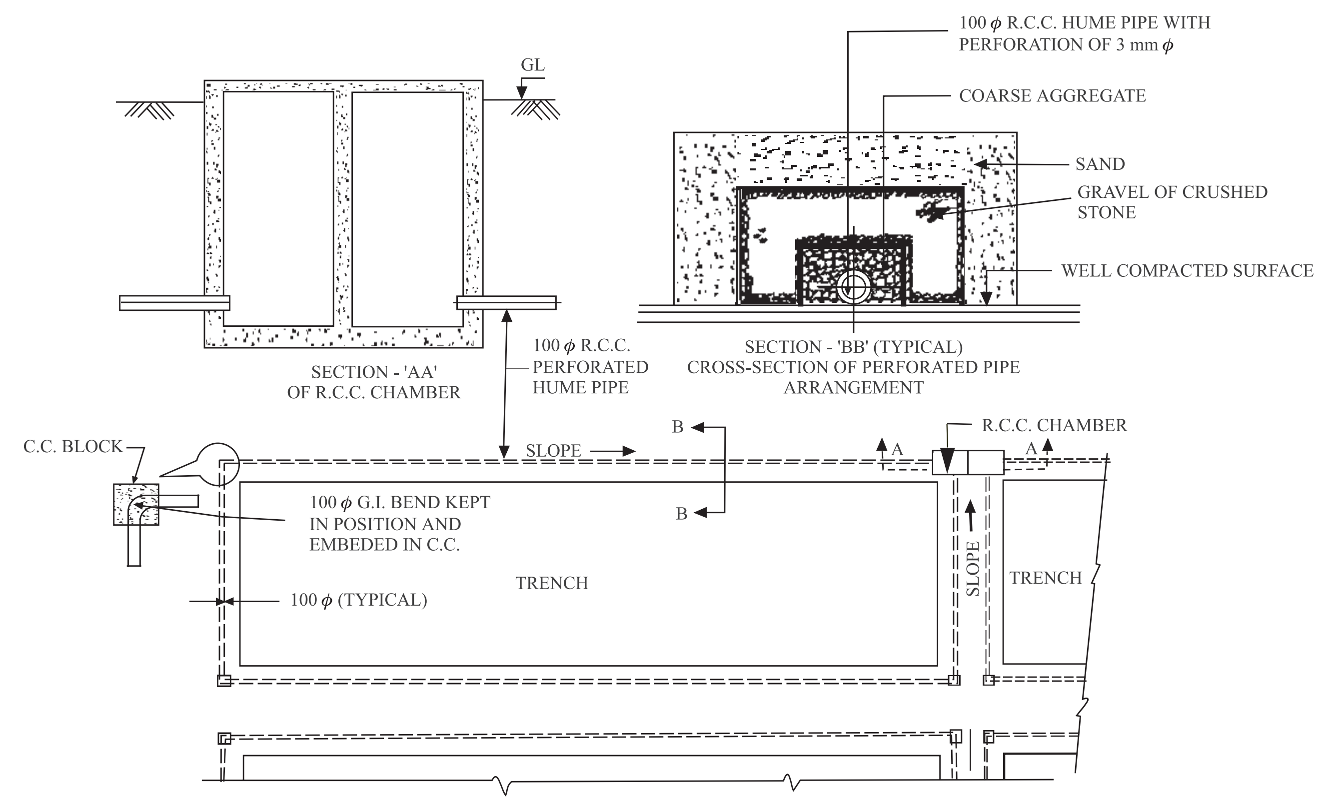


FIG. 7 : RETRIEVABLE HIGH INTEGRITY CONTAINER (HIC)



NOTE : ALL DIMENSIONS ARE IN mm UNLESS SPECIFIED

FIG. 8 : TYPICAL WATER MONITORING IN REINFORCED CEMENT CONCRETE TRENCH



NOTE : ALL DIMENSIONS ARE IN mm UNLESS SPECIFIED

FIG. 9 : TYPICAL SUBSOIL WATER COLLECTION AROUND REINFORCED CEMENT CONCRETE TRENCH

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LIST OF PARTICIPANTS

WORKING GROUP

Dates of meeting :			
	02/09/1992	25/09/1992	27/11/1992
	08/12/1992	15/01/1993	05/02/1993
	17/02/1993	26/02/1993	12/03/1993
	23/03/1993	12/05/1993	04/06/1993
	20/06/1993	18/08/1993	08/09/1993
	27/09/1993	19/10/1993	08/11/1993
	17/11/1993	25/11/1994	29/11/1995
	30/05/1996	07/06/1996	27/05/1997
	05/08/1997	09/12/1997	22/08/1998
	06/11/1998	01/02/1999	01/03/1999
	23/03/1999		

Members of the working group:

Shri R.C. Rastogi (Convenor till April, 1993) : BARC

Shri P.D. Sharma (Chairman) : NPCIL

Shri S.B. Bodke : BARC

Shri N.B. Joshi : NPCIL

Shri G.S. Jauhri : BARC

Shri S.K. Chopra : NPCIL

Shri P. Shekhar : BARC

Shri G. Natarajan (Member-Secretary) : AERB

ADVISORY COMMITTEE ON CODES, GUIDES AND ASSOCIATED MANUALS FOR SAFETY IN DESIGN (ACCGD) OF NUCLEAR POWER PLANTS

Dates of meeting	:	September 7, 1995 October 12 & 13, 1995 April 11, 2000

Members participated in the meeting:

Shri S.B. Bhoje (Chairman)	:	Director, IGCAR
Shri S. Damodaran	:	NPCIL (Former)
Shri V.K. Mehra	:	BARC
Shri Umesh Chandra	:	NPCL
Prof. N. Kannan Iyer	:	IIT, Bombay
Shri Deepak De	:	AERB
Shri S. Sankar	:	BARC
Shri K.K. Vaze	:	BARC
Shri C.N. Bapat	:	NPCIL
Dr. S.K. Gupta	:	BARC
Shri S.A. Bhardwaj	:	NPCIL
Shri R.S. Singh (Member-Secretary)	:	AERB (Former)
Shri S.A. Khan (Member-Secretary)	:	AERB

ADVISORY COMMITTEE ON NUCLEAR SAFETY (ACNS)

Date of meeting	:	January 18, 2002

Members participated in the meeting :

Shri Ch. Surender (Chairman)	:	NPCIL (Former)
Shri S.K. Sharma	:	BARC
Dr.V. Venkatraj	:	BARC
Shri R.K. Sinha	:	BARC
Shri S.P. Singh	:	AERB (Former)
Shri R.D. Marathe	:	L & T
Shri S.S. Bajaj	:	NPCIL
Shri S.K. Agarwal	:	AERB
Shri K. Srivasista	:	AERB

PROVISIONAL LIST OF SAFETY CODES, GUIDES AND MANUALS ON DESIGN OF PRESSURISED HEAVY WATER REACTORS

Safety Series No.	Provisional Title
AERB/SC/D	Code of Practice on Design for Safety in Pressurised Heavy Water Based Nuclear Power Plants
AERB/SG/D-1	Safety Classification and Seismic Categorisation
AERB/SG/D-2	Structural Design of Irradiated Components
AERB/SG/D-3	Protection Against Internally Generated Missiles and Associated Environmental Conditions
AERB/SG/D-4	Fire Protection in Pressurised Heavy Water Reactor Based Nuclear Power Plants
AERB/SG/D-5	Design Basis Events for Pressurised Heavy Water Reactors
AERB/SG/D-6	Fuel Design for Pressurised Heavy Water Reactors
AERB/SG/D-7	Core Reactivity Control in Pressurised Heave Water Reactors
AERB/SG/D-8	Primary Heat Transport System for Pressurised Heavy Water Reactors
AERB/SG/D-9	Process Design
AERB/SG/D-10	Safety Critical Systems
AERB/SG/D-11	Emergency Electric Power Supply Systems for Pressurised Heavy Water Reactors
AERB/SG/D-12	Radiation Protection in Design
AERB/SG/D-13	Liquid and Solid Radwaste Management in Pressurised Heavy Water Reactor Based Nuclear Power Plants

PROVISIONAL LIST OF SAFETY CODES, GUIDES AND MANUALS ON DESIGN OF PRESSURISED HEAVY WATER REACTORS (contd.)

Safety Series No.	Provisional Title
AERB/SG/D-14	Control of Air-borne Radioactive Materials in Pressurised Heavy Water Reactors
AERB/SG/D-15	Ultimate Heat Sink and Associated Systems in Pressurised Heavy Water Reactors
AERB/SG/D-16	Materials Selection and Properties
AERB/SG/D-17	Design for In-Service Inspection
AERB/SG/D-18	Loss of Coolant Accident Analysis for Pressurised Heavy Water Reactors
AERB/SG/D-19	Hydrogen Release and Mitigation Measures under Accident Conditions in Pressurised Heavy Water Reactors
AERB/SG/D-20	Safety Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants
AERB/SG/D-21	Containment System Design
AERB/SG/D-22	Vapor Suppression System for Pressurised Heavy Water Reactors
AERB/SG/D-23	Seismic Qualification
AERB/SG/D-24	Design of Fuel Handling and Storage Systems for Pressurised Heavy Water Reactors
AERB/SG/D-25	Computer Based Safety Systems
AERB/SM/D-1	Decay Heat Load Calculations