AERB SAFETY MANUAL NO. AERB/SM/DECOM.-1

DECOMMISSIONING

OF

NUCLEAR FACILITIES

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Atomic Energy Regulatory Board
Mumbai 400 094

FOREWORD

The terms of reference specifying the functions of AERB include, amongst others: development of safety codes, guides and standards for siting, design, construction, commissioning, operation and decommissioning of the different types of plants, keeping in view international recommendations and local requirements, and develop safety policies in both radiation and industrial safety areas, advise AEC/ DAE on technical matters that may specially be referred to the Board in connection with siting, design, construction, commissioning, operation and decommissioning of the plants under DAE.

AERB has published safety documents on siting, design, construction, commissioning and operation of nuclear fuel cycle facilities and considered it necessary to cover decommissioning aspects as well, in order to complete its assigned functions. This safety Manual on Decommissioning of Nuclear Facilities is the first step in this direction.

AERB is of the view that every organisation should focus attention on the decommissioning of nuclear facilities after completion of their useful life. AERB is aware that, internationally there is a growing interest in plant life extension due to economic considerations. Regulatory bodies stipulate upgradation of safety features based on international experience and current safety standards. However, decommissioning becomes a necessity at some time after the extended life of the plant. Nuclear industry has demonstrated that, with modern technological developments, decommissioning of nuclear facilities can be carried out without undue risk to the occupational workers, members of the public and protection of the environment.

In view of limited experience in the field of decommissioning, this document is being issued as a Safety Manual instead of a Safety Guide. This Manual elaborates the various technical and safety considerations in the decommissioning of nuclear facilities including ultimate disposal of radioactive materials/ wastes generated during decommissioning. Details that are required to be furnished to the regulatory body while applying for authorisation for decommissioning and till its completion are enumerated. This manual is issued to assist DAE units in formulating a decommissioning programme. Since the subject of decommissioning of nuclear facilities is a continuously evolving process, AERB is of the view, that provisions of this manual will apply for a period of five years from the date of issue and will be subsequently revised, if necessary.

AERB places on record grateful thanks to all members and organisations who have contributed to the preparation, review and amendments of this manual.

P. Rama Rao

(P. Rama Rao)
Chairman, AERB

DEFINITIONS

Approval

A formal consent issued by the Regulatory Body to a proposal.

Atomic Energy Regulatory Board

National authority designated by the Government of India having the legal authority for issuing the regulatory consents for various activities related to a facility and to perform safety and regulatory functions including enforcement for the protection of the public and operating personnel against radiation and Factories Act for Department of Atomic energy.

Clearance Level (CL)

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

A national or state authority designated or otherwise recognised as such for a specific purpose. As per Atomic Energy Act, AERB is the designated body.

Conditioning of waste

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.

Confinement

Barrier which surrounds the main parts of a nuclear facility carrying radioactive materials and designed to prevent or to mitigate uncontrolled release of radioactivity to the environment during commissioning, operational states, during design basis accidents or decommissioning phase.

Contamination

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

Containment

If the design of the confinement is to withstand internal pressure that can be expected to result from design basis accidents, it is generally called containment.

Decommissioning

The process by which a 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 the environment.

Decontamination

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

Decontamination Factor

The ratio of initial level of contamination of radioactive material to residual level achieved through a decontamination process.

Disposal

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

Documentation

Recorded or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures and results.

Long-lived wastes

Long-lived waste is that waste containing radionuclides, which will not decay to acceptable levels during the tenure of institutional controls.

Nuclear facility

A facility and its associated land, buildings and equipment in which radioactive material is produced, processed, used, handled, stored or disposed of (for example repository) on such a scale that consideration of safety is required.

Operating Organisation

The organisation so designated by a responsible organisation and authorised by the Regulatory Body to operate the facility.

Prescribed limits

Limits established or accepted by the Regulatory Body for specific activities or circumstances that must not be exceeded.

Quality Assurance

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

Regulatory Consent

It is a written permission issued by the Regulatory Body to perform the specified activities related to the facility. The types of consent are 'Licence', 'Authorisation', 'Registration', and 'Approval' and will apply depending upon the category of the facility, the particular activity and radiation sources involved .

Responsible Organisation

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

Safety

Protection of all persons from undue hazard.

Short-lived wastes

Refers to radioactive wastes, 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.

Site

The area containing the facility defined by a boundary and under effective control of facility management.

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.

Surveillance

All planned activities namely 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 operation

A document submitted on behalf of or by the responsible organisation covering operational limits and conditions, surveillance and administrative control requirements for operation of the facility and approved by the Regulatory Body.

Unrestricted release/use

Any release/use of materials, equipment, buildings or site without restriction imposed by the Regulatory Body.

CONTENTS

1. INTRODUCTION

1.1 General

Industrial plants are taken out of service when they are no longer safe and economical to continue their operations. The plant may be either taken apart or adapted for other uses. In the case of nuclear facilities, the radiation-induced damage to some of the key components adds a new dimension to the safe operation of the facility. The presence of radioactivity in the system such as piping, equipment and structures also pose additional challenges. In view of the radiation environment, regulatory controls are required to be extended to decommissioning operations as well. This manual sets forth the requirements for decommissioning of an operating nuclear facility at the end of its service life. It provides information on decommissioning, acceptance criteria and their bases, health and safety considerations including waste management, documentation requirements and quality assurance practices to be adopted. An outline of design provisions to facilitate decommissioning and a discussion on organisational aspects are also included.

1.2 Purpose of the manual

The purpose of this manual is to provide the regulatory framework of safety within which the decommissioning of nuclear facilities is to be carried out.

1.3 Scope of the manual

Only those aspects, which are directly related to radiological safety, are discussed. The recommendations in this manual are the minimum requirements, which should be met in order to achieve safe decommissioning of nuclear facilities. Aspects such as industrial safety, chemical toxicity, etc., are not covered. For more information on these topics, reference may be made to AERB codes and guides or other relevant documents [1, 2, 3, 4].

2. OBJECTIVES OF DECOMMISSIONING

2.1 **The Main Safety Objectives of Decommissioning are:**

2.1.1 Decontamination and disassembly of facility, to the extent necessary, the facility and to clean up the site to levels acceptable for:

i) limited use by a responsible organisation in a planned manner and as approved by AERB; or
ii) unrestricted use by the public.

2.1.2 Protection of the workers, the public and the environment from the radiological and non-radiological hazards resulting from decommissioning and

2.1.3 Compliance with the prescribed limits to ensure that all radiation exposures are kept below the set limits and as low as reasonably achievable (ALARA)

2.1.4 Minimisation of the burden on future generations taking into account social and economic factors in general.

2.1.5 Selection of the decontamination process such that the resulting radioactive waste is safely and effectively managed.

3. PROTECTION CRITERIA

3.1 Occupational Exposures

All occupational exposures arising out of decontamination, dismantling and waste collection, conditioning and disposal operations shall be governed by the dose limits and provisions contained in the Manual of Radiation Protection for Nuclear Facilities as amended from time to time [5].

3.2 Discharge of Radionuclides to the Environment

Consistent with the statement in Section 4.1, the new technical specifications for the decommissioning phase shall contain, interalia, limits for discharge of radionuclides to the environment.

3.3 Criteria for Long Term Waste Disposal

Not withstanding the provisions of Section 3.2 above, the following dose limits are prescribed for the facilities mentioned here under:

3.3.1 The dose limit for members of the public due to a near surface disposal[1] facility shall not exceed 100 micro Sievert (μSv) in a year.

3.3.2 The dose limit for members of the public from a deep geological repository shall not exceed 100 microSievert in a year.

3.4 Clearance Level (CL)

During decommissioning, appreciable quantities of valuable metals and equipment may become available for recycling or reuse. Useful materials arising out of decommissioning can be released for unrestricted use by members of the public provided the resultant individual dose to members of the public shall not exceed the limits specified by the Competent Authority for that purpose. A number of studies have been undertaken by IAEA and other agencies, from time to time, proposing levels of radionuclides in solid materials below which there need to be no regulatory controls or withdrawal of regulatory control on the premise that the associated radiation hazards are trivial. A set of these clearance levels and the basis of establishing these are given in Annexure-1 and reference [6].

Note: Annexure-1 gives the derivation of the criteria mentioned in section 4.3 and 4.4.

[1] Near surface disposal refers to the emplacement of radioactive solid, solidified waste with or without engineered barriers at near surface below or above ground level.

4. STRATEGY [7]

4.1 General Considerations

The process of decommissioning begins after the final shutdown[2] of the facility and ends with the release of the site for use by a responsible organisation as authorised by AERB or for unrestricted use by the public. Prior to decommissioning, a decommissioning plan would have been prepared by the operating organisation (See Section 6.4 and Annexure-2). The plan needs approval by AERB before the start of decommissioning.

As a result of abnormal events, the facility may have to be prematurely retired before the end of its expected operating life. In such a case, prior to taking up the decommissioning, the facility shall be first rendered to a state that it no longer causes release of radioactive material to the environment. The decommissioning plan shall be further established or modified taking into account the abnormal event.

The Technical Specifications for operating facilities will cease to be valid after the final shutdown of the facility. A new set of technical specifications will have been prepared by operating organisation and approved by AERB based on the evaluation made on the decommissioning plan. (Sec 3.2 and 11.2)

In facilities that had handled fissile materials, the possibility that some residual fissile material may remain in the system shall be given consideration during decommissioning and suitable precautions shall be taken. [8]

Facilities for which confinement of radioactivity cannot be assured after final shutdown, due to structural degradation, should either be taken up for immediate decommissioning or put under a new confinement.

Major decommissioning activities as applicable to various nuclear fuel cycle facilities are indicated in Annexure-3A, 3B and 3C.

Decommissioning may be carried out in one continuous operation following final shut down (prompt decommissioning) or in a series of discrete operations over an extended time period (delayed decommissioning).

4.2 Preparatory Steps

4.2.1 Major activities during this phase include the following:

a) Transfer of fuel from the plant boundary as practicable;
b) Removal of process radioactive materials and easily removable systems, equipment and components; and

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[2] The shutting down of a facility at the end of normal operating phase.

c) Stabilisation and sealing of systems containing radioactive material.- Stabilisation in a nuclear facility means putting the facility in a stable condition by ensuring sub-criticality of the fissile materials present, adequate cooling of radioactive materials, and adequate control on spread of contamination.

4.2.2 Plant components, systems and structures, which are highly radioactive and not easily accessible, are left intact. The plant should remain under surveillance of trained operation and maintenance staff till further decommissioning is taken up.

4.2.3 The contamination barrier[3] shall be kept as it was during operation. All openings of the process systems shall be permanently blocked and sealed with valves, plugs, blanks etc. If necessary, checks should be carried out to ensure that there are no visible leaks inside the contamination barrier.

4.2.4 Containment building should be kept in a state appropriate to the potential hazard and the atmosphere inside the building should be under control.

4.2.5 Access control should be enforced. Access into the facility should be subject to monitoring and surveillance procedures.

4.2.6 All utilities such as ventilation system, electric power supply, compressed air system, waste handling and treatment systems, fire fighting systems, service water system, mechanical handling equipment including monitoring systems for radiation and fire hazards should be operable[4] for further safe decommissioning.

4.2.7 All relevant as-built construction drawings including alterations should be available for consultation at this stage. (See section 11.1)

4.3 Decommissioning Phase for Restricted Site Release

Major activities during this phase are:

4.3.1 Transfer of fuel from the plant boundary, if it had not been done earlier.

Extensive decontamination and/or dismantling of radioactive parts of the plants may be carried out. The parts so treated may be stored for further radiological decay or disposed off as radioactive waste. Parts whose radioactivity level conforms to the Clearance Level (CL) may be released as appropriate. Decontaminated areas themselves may be considered for restricted or unrestricted use as authorised by AERB.

Sealing of remaining radioactive parts of the plant by physical means for further reduction in radiation dose rates due to radiological decay under surveillance.

[3] A stucture/system that delays or prevents radionuclide migration from source material.

[4] Poised to function in the manner as envisaged in the design.

4.3.4 Reduction of the contamination barrier to the required size after decontaminating and/or dismantling parts of the plant.

4.3.5 Modifications to containment building as also the nuclear ventilation system as per the radiological safety requirements.

4.3.6 Continuances of surveillance as appropriate for radiological safety, structural integrity and operability of remaining utilities.

4.4 Decommissioning Phase for Unrestricted Site Use

4.4.1 This phase involves:

Removal of all radioactive parts of the plant

a) either for release to the public after achieving required decontamination to Clearance Level (CL) or

b) to solid waste management facility. (See section 4.5 below)

4.4.2 The final radiation survey shall be carried out to ensure that residual radioactivity level on the site conforms to Clearance Level (CL). Following the survey, the site is released for unrestricted use and no further surveillance, inspection or tests are required.

4.5 Wastes from Decommissioning

4.5.1 During all the phases mentioned in Sections 4.2, 4.3 and 4.4 above especially 4.3 and 4.4 there may accumulate large quantities of equipment and materials, some of which may be of economic value. If these articles contain radioactivity at concentrations below the Clearance Levels given in Annexure-1, then they may be released to the public either for unrestricted use or for restricted use with or without clearance, as the case may be, by the Competent Authority.

4.5.2 The remaining material and equipment (refer section 7.3) shall be deemed as radioactive waste and treated and disposed off in a manner outlined in Section 7.6.

5. DESIGN PROVISION/CONSIDERATIONS FACILITATING DECOMMISSIONING [7, 8, 9, 10]

5.1 Provisions incorporated at the site selection, design, construction commissioning and operation phases of the facility with due consideration for decommissioning would facilitate in reducing occupational exposure. Some of these provisions could also benefit facility operation and maintenance, reduction in wastes generated and make decommissioning easier. (Sections 7.4, 8.5 and 8.6)

5.2 In most of the facilities, large size equipment are installed at the time of construction/erection when they are not radioactive and other surrounding structures are built subsequently. This results in major handling and radiation exposure problems while planning for replacement for life extension or decommissioning. Therefore, design should take care of provisions for easy dismantling of highly active equipment and their disposal during decommissioning.

5.3 While compact plant layout for locating various systems, equipment and components is beneficial from cost considerations, personnel access and equipment movements during decommissioning, especially for those, which are highly radioactive, deserve equal attention. These aspects should be given due consideration while designing the facility and its plant layout.

5.4 Any design feature introduced to make decommissioning easier shall not conflict with the basic safety requirement.

5.5 Choice of locations and layout of the nuclear facility such as above or below the grade should be carefully considered keeping in view that the facility may be required to be kept under safe surveillance during extended periods of decommissioning. This is specifically applicable to plants located near sea shore, in seismic zones or in flood prone areas.

5.6 Provisions to Facilitate Decommissioning

5.6.1 Material selection to minimise induced radioactivity and activation of corrosion products.

Use of Co-free-Ni, avoiding use of Stellite (e.g. use of Colmonoy) to obtain hardened surface particularly for valve seats, replacement of Monel tubes for steam generators with Incoloy-800 etc.

Material selection for core components such as reactor vessel, calendria tubes, thermal shields and concrete biological shield to prevent/minimise build-up of long-lived induced radioactivity.

5.6.2 Detailed analysis of as-built structural materials for predicting the activation products for characterisation of the radioactive nuclides, estimation of radioactivity build-up, decay pattern of activated products and dose rate at later stage. Preservation of samples of original construction materials and installation of in-core coupons for further analysis/studies to be carried out later. Sufficient provision for remote monitoring of radiation fields in inaccessible areas for radiological assessment.

5.6.3 Protection and treatment of the inner surfaces of the equipment/pipe to minimise deposition of activated corrosion products (viz. electro-polishing, hot-conditioning etc.)

5.6.4 Protection of concrete surfaces with suitable covering to avoid contaminant penetration (such as peelable paints or stainless steel cladding etc.) as appropriate depending on the contaminant potential

5.6.5 Provision of easily removable non-absorbing thermal insulating medium (such as mirror insulation or insulating medium enclosed in metallic jackets)

5.6.6 Proper layout and location of the equipment and components which are likely to get activated during operation, for easier access and removal

5.6.7 Provision of lifting features on the components/equipment, wherever possible, to aid remote removal of the radioactive components/equipment.

5.6.8 Material handling facilities of appropriate capacity

5.6.9 Segregation of flooring in the form of removable concrete slabs/blocks within the reach of the plant material handling equipment.

5.6.10 Proper sloping of floor to metal lined sumps to facilitate collection of leaking fluid and floor washings

5.6.11 Access and hatch requirements to remove the largest size equipment either intact or with minimal cutting

5.6.12 Provision of removable concrete shielding wall (with prefab concrete blocks).

5.6.13 Chemistry control measures to minimise corrosion and thus minimisation of activated corrosion products in piping/equipment.

5.6.14 Means for evaluating the structural integrity during the design life and beyond the design life during decommissioning phase.

5.6.15 Laying underground pipe lines in waterproof concrete trenches with suitable inspection/surveillance facility to avoid sub-soil contamination in the event of leakage.

5.6.16 Piping layout for active process fluids should eliminate dead zones and low velocity areas to prevent deposition of crud.

5.6.17 Selection of appropriate design and specification for fuel elements and operating conditions to minimise fuel clad failure thus obviating activity accumulation during operation phase.

5.6.18 Provision of on-line decontamination facility including periodic full system decontamination facility for the plant towards periodic clean up during operational phase to prevent accumulation of radioactivity.

5.6.19 Design features incorporated and quality of constructions should be such that failures in waste handling system during operation phase would not lead to difficulty during decommissioning.

5.6.20 Requirement of temporary local ventilation compatible with the main ventilation system should be assessed and incorporated.

5.6.21 Provision of boreholes at the site of nuclear facility towards detection of any sub-soil contamination and its migration.

5.7 Waste Reduction Techniques

5.7.1 Activated or contaminated concrete forms a major source of waste during decommissioning. To minimise this waste, the entire biological shield can be fabricated from precast steel-reinforced interlocking blocks held together by steel bands and bolts or the inner region of the shield can be fabricated from a plaster-like material applied in layers. In the former case, only the activated blocks need to be removed for controlled disposal. In the latter case, the radioactive portions of the shielding can be demolished easily and removed.

5.7.2 Steel plates or gratings in place of concrete slabs have the merit of reducing surface contamination. Waste volumes generated would be considerably less since steel is more easily decontaminatable than concrete.

5.7.3 Drip trays and floor curbs suitably sized and placed to contain the spills, decontamination of selected materials and components to low levels, contamination control measures such as tents and hoods, administrative controls and use of trained personnel are additional factors that help in reduction of waste generation.

6. DECOMMISSIONING-INFLUENCING FACTORS [7]

6.1 Major Factors Influencing Decommissioning Decision

6.1.1 Safety considerations: Closure of a facility due to safety reasons could arise, if, for example, reliability of the safety system is impaired due to ageing and suitable refurbishing for life-extension is not technically or economically feasible. There may also be a need to adopt backfitting as appropriate to meet applicable safety standards. If it is found that such backfitting is uneconomical or technically not possible, the facility may have to be decommissioned.

6.1.2 Technical aspects: Closure on obsolescence grounds might arise when an alternative facility is available which offers better technology or has wider applications. In many cases, such as a research reactor or a pilot plant, the facility is commissioned for a specific programme at the end of which closure may be necessary.

6.1.3 Major damage to the facility: In certain cases, due to a major accident, a nuclear facility may not be in a position to be rehabilitated for further safe operation and may need decommissioning.

6.1.4 Economical aspects: There may be instances where even after all practicable cost saving operations related to facility have been achieved, the operating costs are still significantly higher than the benefits accrued from the facility. As a result, a decision to close the facility on economic grounds may have to be taken.

6.2 Major Factors Influencing Selection of Decommissioning Time Periods [8][11]

6.2.1 Location and status of the facility.

6.2.1.1 Location, size and type of the nuclear facility, including an estimation of the amount of radioactivity and its type.

6.2.1.2 Multi-unit or single unit at the location.

6.2.1.2 Single-unit locations require dedicated personnel for monitoring and surveillance in case of decommissioning with extended periods. In case of multi-unit locations, required technical support can be provided by other operating unit(s) at the location.

6.2.1.3 Mechanical instability of various structures during decommissioning taking into account the following factors:

a) Ageing (cracking & creep) as a result of neutron bombardment and gamma irradiation and the time-dependent degradation of material;

b) Change in external forces due to floods, high winds, rainfall and other natural events of larger magnitude than assumed in design occurring during extended "cooling" and/or decommissioning phases;

c) Change in loads arising out of the decommissioning operations (e.g. cutting, blasting etc.) and their sequence;

d) Residual resistance to seismic activity or any other external events such as severe gales and floods etc; and

e) Condition of ventilation system and integrity of confinement.

6.2.2 Site characteristics detailed below are updated upto the time of decommissioning:

a) Local topography for continued availability of access to heavy transportation means.

b) Geological conditions of site such as seismic wave propagation, soil characteristics, water table and its seasonal fluctuations etc.

c) Local demography and ecology projected population distribution, land use, infrastructure available in the area, food habits etc.

6.2.3 Future Utilisation of Site

In view of the considerable time, technical efforts and resources spent on selecting nuclear sites, they represent a valuable resource in terms of low seismic activity, available cooling water, access to major transportation routes, desirable demographic patterns and above all public acceptance through environmental impact analysis. As a result, an operating organisation may usually consider the merits of replacement facilities in the same site. It may even be economically viable to dismantle the facility completely including inactive components to make room for a replacement facility.

In multi-facility sites, personnel at the operating facilities may be available for continuing maintenance, surveillance and security for the initial decay, dismantling and /or decontamination stages at relatively low incremental costs. Items such as turbines, water treatment and circulating systems, warehouses, buildings and other structures may be found useful for non-nuclear uses.

6.2.4 Availability of Locations for Disposal of the Radioactive Materials

Availability of off-site locations for final disposal of radioactive wastes from decommissioning of the facility, in the event of inadequacy of the existing waste disposal facility on-site.

6.2.5 Safety Considerations

6.2.5.1 Considerations of safety include the following:

a) radiological safety taking into account that the original containment barriers are breached;
b) industrial safety during dismantling operations;
c) doses to workers and members of the public due to routine or accidental releases of radioactivity; and
d) hazards to workers and the public during shipment of radioactive material to disposal site.

6.2.5.2 While ensuring that the chosen techniques of dismantling and decontamination do not significantly reduce the industrial, nuclear or radiological safety of workers, the following factors should be noted:

a) Blockage of emergency escape routes;
b) Increased fire hazards or exposure to hazardous or toxic substances;
c) Increased hazards due to new electrical installations, inadequate lighting, increased noise levels or inadequate heating, ventilation and air conditioning; and
d) Impediments to store, or handle materials, to work or to walk in areas because of new equipment or operations.

6.2.6 Technical Considerations

6.2.6.1 Mechanical handling equipment and service systems should be available continually during different stages of decommissioning, including the means of monitoring and surveillance of the physical and radiological conditions of the plant.

6.2.6.2 Considerations should be given to the availability of newer equipment, techniques and/or facilities resulting in faster and/or better means of dismantling or intact removal of major contaminated equipment thereby saving cost and/or manrem. Improvement in remotisation of such equipment and techniques should also be considered.

6.2.6.3 All systems, techniques and methods should have preferably the following criteria:

a) Fail-safe design;
b) Reliability, durability;
c) Easy maintainability, repair and dismantling;
d) Ease of decontamination;
e) Radiation tolerant components;
f) Compatibility with environmental conditions obtainable during decommissioning; and
g) Simplicity in design.

6.3 Training of Workers

For a successful decommissioning programme, trained manpower is an essential prerequisite. Training of workers in decontamination and dismantling should be done well before the decommissioning starts. Disassembly of equipment and structures should be done under supervision of professional dismantlers. Supervisory personnel should also be given training in radiation protection. Lessons learned out of experience in decommissioning should be shared by other workers. These factors have the merits of optimal use of equipment and facilities, reduction in doses and in waste volumes and quantities.

6.4 Planning for Decommissioning [7,11]

6.4.1 The responsible/operating organisation shall prepare a decommissioning plan (Annexure-2) detailing out all steps/activities towards ultimate release of site for unrestricted/restricted use and submit the same to AERB for approval before the start of decommissioning.

The facility would be permitted for decommissioning only after the detailed decommissioning plan, as given in the Annexure-2, is submitted to and approved by AERB.

The approved decommissioning plan, if required, should be updated on the basis of periodic monitoring by AERB.

6.4.2 For facilities, which are already in operation, a preliminary decommissioning plan shall be prepared and submitted to AERB within five years of publication of this manual. This plan shall be reviewed periodically and updated taking into account any significant event during the operational phase of the facility as required by AERB. This review also shall take into account technological progress, changes to the facility and current regulations.

6.4.3 For a new facility, before the construction license or operation license is issued, a preliminary decommissioning plan shall be submitted to AERB to show that decommissioning of the facility can be carried out safely at a future date.

Features which would facilitate easy decommissioning at a future date, should be assessed and incorporated during design and construction stages and such features shall not conflict with basic safety requirements (Section 5).

The preliminary plan submitted before the construction shall be updated during the operation phase and the final plan shall be prepared as in section 6.4.1, before decommissioning the facility.

6.5 Funding and Costing

6.5.1 Prior to start of decommissioning, the operating/responsible organisation shall have established a corpus fund or similar arrangements to provide adequate finance to cover the cost of decommissioning. The money may be raised through a small addition to the unit power cost or other means of funding. An estimate of the cost of decommissioning and details of the availability of funds should be furnished to AERB along with the decommissioning plan.

Cost of decommissioning should include planning and engineering during post-operation phase, decontamination and dismantling and transportation and disposal of radioactive wastes from decommissioning. It should also include cost of maintenance, surveillance and security of the facility particularly if decommissioning or part of it is deferred for a prolonged period so as not to impose undue financial burden on future generations.

Source of the fund should also be indicated if the facility were to suffer premature shutdown.

Costing methods for decommissioning should include costs of the particular option (e.g. immediate or delayed decommissioning) taking into account changes in the costs overtime due to changes in regulatory requirements, escalation of cost, and modernisation in techniques.

7. DECOMMISSIONING PROCESS AND WASTE MANAGEMENT

Decommissioning of a nuclear facility involves decontamination, dismantling, cutting, packaging & transportation, of plant equipment/materials; handling, treatment, conditioning, storage/disposal of radioactive/inactive wastes generated.

Methods followed for decontamination & disassembly, sources of wastes and techniques adopted for reduction/conditioning that are appropriate for liquid and solid radioactive wastes resulting from decommissioning are discussed in succeeding subsections. The factors involved in selection of proper disposal facilities for various types of waste are also discussed.

7.1 Decontamination:

7.1.1 General Considerations

7.1.1.1 Decontamination during decommissioning is intended to reduce the radioactivity contained in deposits, oxide films and dust in the facility for the following reasons:

a) To minimise the radiation exposure to decommissioning staff and public;
b) To reduce radionuclide concentrations in wastes for optimal use of the waste repository; and
c) To recover or reuse the materials.

7.1.1.2 The processes usually followed include chemical decontamination, mechanical decontamination using vacuum cleaning, washing or scrubbing with or without solvents, water/steam jetting, abrasive jetting, spalling and other processes like ultrasonic cleaning, melting etc. The current technological development should also be considered and taken into account.

7.1.1.3 Factors for selecting the decontamination process should be considered.

7.1.1.4 Analysis should be carried out by extensive experimental work on samples selected from system/facility before final choice of the process is made. An analysis may be made to examine the worth of decontaminating the facility to decide if a soft decontamination[5] at a low cost is more advantageous than a hard decontamination[6] at a higher cost with the attendant problems in treating the resulting waste.

7.1.1.5 A decontamination process for a site specific application should be selected taking into account factors such as type of plant and its operating history, type of surface-external or internal, type and composition of contaminant, decontamination factor (D.F.) required etc. Other factors needing consideration are quantity, treatment and conditioning of secondary waste generated, availability of trained staff, extent to

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[5] The decontamination process in which neither the material nor its specification is affected.

[6] The decontamination process which affects the material on which the contaminant was deposited and/or its specification.

which the plant needs to be decontaminated, occupational & public doses, and the need to keep the doses ALARA.

7.2 Disassembly

7.2.1 The dismantling of nuclear reactors and other facilities contaminated with radioactivity generally involves the segmentation of metal items such as reactor vessels, tanks, piping and other components. In addition, in most facilities to be decommissioned, scarification of the concrete surface to remove activated/ contaminated layers and/or demolition of concrete components are required.

7.2.2 The cutting tools/processes applicable to metal components include: arc saw, spark erosion, plasma arc cutting, oxygen burning, thermite reaction lance, explosive cutting, hacksaws, guillotine saws, band saws, abrasive cutters, circular cutters, and pipe crimpers.

7.2.3 Concrete removal processes include: controlled blasting, wrecking ball, rams, flame cutters, rock splitter, sawing, drilling, explosive cutting, drilling and spalling, scarification and sand/water/shot blasting.

7.2.4 In case the components to be cut or scarified are highly radioactive, the equipment used in the above techniques may be required to be operated remotely. As such, a wide range of techniques and specialised equipment may have to be developed well in advance in connection with the dismantling task in the decommissioning of nuclear facilities to prove their workability.

7.2.5 Many disassembly operations may have to be carried out in the presence of a radiation field, thus necessitating use of devices that can position and operate disassembly tools without exposing operating personnel to radiation exposure. Remote controlled devices like tele-operators and robotics are often required to be developed for the task of disassembly, handling of radioactive materials, decontamination of contaminated areas etc. Proper precautions should be taken to establish the capability of such a device to handle disassembly tools, materials, segments etc. Efforts should be made to make use of current developments in the techniques used and newer techniques, if any.

7.3 Waste Generation

7.3.1 General

Waste generated in the decommissioning of a nuclear facility will vary widely depending upon the nature of the facility viz.; nuclear reactor, spent fuel reprocessing plant, radioisotope production facility etc. and the extent of decontamination and processes employed.

The waste will consist of radioactive as well as inactive waste, the latter forming a large bulk. Although the nuclear fuel and the process materials would have been removed from the facility before the decommissioning process begins, residual radioactivity will remain in the systems in almost all cases and this will have to be accounted for. Generally, the radionuclides present in nuclear facilities being decommissioned can be classified into the following:

a) naturally occurring radionuclides of the uranium and thorium series in fuel processing plants;

b) radioactive products induced by:

   the fission process (fission products); and
   neutron activation of certain elements in the reactor core or reactor components and nearby structures or in the coolant.

In addition, there may be daughter radionuclides, which may accumulate to significant amounts after periods of decay.

The residual radioactivity that remains in the systems after the fuel and process materials are removed may be entrained in the materials or have deposited on the surface of the facilities in the system. In case of nuclear reactors, the induced radioactivity of the reactor structures presents an additional source.

7.3.2 Nuclear Power Plants

Typically, in a nuclear power plant, the wastes generated during decommissioning will contain steel, stainless steel, special alloys including zirconium alloys, aluminium, reinforced concrete etc. The radionuclides of concern may be ^{60}Co, ^{51}Cr, ^{63}Ni, ^{94}Nb, ^{108m}Ag, ^{59}Ni and ^{14}C.

In pressurised heavy water reactors, ^{3}H will be of additional concern. ^{65}Zn may also pose problems in the initial stages or if prompt decommissioning is the option. There may also be contamination by fission products and traces of transuranics if the reactor had operated with defective fuel.

In the decommissioning of a nuclear power plant, active components from reactor system, radioactive (rad) waste system, turbines and other auxiliary systems consisting mainly of metallic components and contaminated concrete structures (biological shield) etc., will constitute the primary decommissioning waste.

After the final shutdown some of the systems such as fuel storage pool, rad waste systems, reactor building, ventilation system etc. will remain operational for quite some time. Wastes from these and from decontamination operations as well as secondary wastes from dismantling activities will constitute operational decommissioning waste and may be in the form of liquids, slurries spent resins, contaminated protective wear, filter cartridges, filters from ventilation system, floor chippings etc.

7.3.3 Fuel Processing/ Reprocessing Facility

In a fuel processing facility, the radioactive components may consist of reaction vessels, filters, centrifuges, sintering furnaces, reducing furnaces etc. The main contaminants are uranium and thorium compounds and their daughter products.
In a reprocessing facility, the radionuclides of concern are the uranium and transuranic isotopes such as ^{233}U, ^{237}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am, etc. In addition, fission products such as ^{90}Sr, ^{137}Cs, ^{134}Cs, ^{144}Ce etc. may be present. The wastes may consist of dissolvers, choppers, condensers of various types, filters, conditioning tanks, feed tanks, solvent extraction columns, intercycle storage vessels, evaporators, ion-exchange columns, product storage tanks and waste storage tanks etc.. Experience has indicated that these solid wastes could be in the range of 0.5 to 1 te of steel per ton of uranium fuel processed. One of the waste products of concern in reprocessing facilities is the organic waste containing TBP, traces of fission products, plutonium and uranium isotopes.

7.3.4 Radiochemical and Radio-metallurgical Facilities

Radiochemical and radio-metallurgical facilities in contrast offer a problem of lesser magnitude in severity. The majority of equipment in these facilities including isotope production facilities can be easily dismantled, decontaminated and/or disposed off as waste. From considerations of cost, entombment of the hot cells appears to be the only viable solution. Plutonium bearing wastes shall be collected in standardised containers which shall be recycled if the wastes contain more than a stipulated quantity, Therefore, very little plutonium will appear in the final wastes released for disposal. Experience indicates that each cu.meter of glove-box/fume-hood space generates roughly an equal volume of solid wastes of different kinds. After entombment of the hot cells, the rest of the laboratory area is reusable.

In facilities, which handle ^{233}U, actinides and ^{208}Tl are of major concern.

Annexure-4 describes different types of radioactive solid and liquid wastes generated during decommissioning of nuclear facilities.

7.4 Waste Reduction and Treatment

7.4.1 Waste Reduction Techniques (See Section 5.7)

Waste reduction techniques are important in view of significant amount of waste generation and also to optimise use of disposal facility. This should be achieved by decontamination, decay etc., and also by volume reduction techniques for liquid and solid wastes.

7.4.2 Treatment Methodologies

Liquid Waste:

7.4.2.1 Techniques such as filtration, chemical treatment, ion exchange and evaporation may be used for decontamination of liquid wastes, singly or in combination, depending upon the characteristics of the waste being treated. While choosing the method of decontamination of various articles, it is important to ensure that the resulting liquid wastes are amenable for treatment. The choice of the treatment process is based on the Decontamination Factor (DF) and the Concentration Factor (CF) which is the ratio of initial volume to final volume of the liquid containing the radioactive ions.

7.4.2.2 The treated liquid effluent may be discharged with or without dilution to the environment after monitoring if the activities are below prescribed limits.

7.4.2.3 In Pressurised Heavy Water Reactor (PHWR) systems, large quantities of tritiated liquid waste are expected to be generated during various decommissioning processes. Adequate storage capacity should be provided before their discharge with or without dilution to meet the regulatory requirements.

7.4.2.4 The concentrates resulting from these processes may be immobilised in cement, bitumen, polymer or glass matrix before storage/disposal in engineered near surface disposal facility within the exclusion zone of the nuclear facility.

Solid Waste:

7.4.2.5 Volume reduction techniques for solid wastes such as incineration and compaction may be used.

7.4.2.6 Ashes resulting from incineration may be immobilised in cement matrix before disposal.

7.4.2.7 Solid wastes, which are neither combustible nor compactable, may be segmented so that standard type of disposable containers can be used.

7.4.2.8 Alpha bearing wastes may need to be segregated during processing and packaging since they require special techniques.

7.5 Waste Packaging and Transportation:

7.5.1 Waste packages and containers for transportation shall be suitably designed to take care of special requirement for decommissioning waste with respect to weight, volume, shape, radiation field and type of contamination. The design shall, in addition to normal considerations, include integrity of container compatible with environmental conditions for interim storage at the disposal site. Interim storage conditions shall indicate quantities of waste to be stored, type of packaging, estimated period of storage, radiation level, type and frequency of monitoring and personnel access requirements. Possible degradation aspects of the container along with its contents shall also be considered.

7.5.2 Standard transport containers shall meet the shielding requirements. For transportation of higher level wastes, temporary shielding can be incorporated to meet prescribed radiation dose rates. In addition to the container, the temporary shielding shall also be properly secured during transportation. The size and shape of various components may need containers of special design. Safety analysis study shall be done to demonstrate the integrity of transport containers. The operating organisation shall ensure that the design of the package, performance standard, procedure for forwarding, transportation etc. conform to requirements stipulated by the Competent Authority. [12]

7.5.3 In case of accidents during transportation outside the facility, i.e. in public domain, AERB Code on Emergency Response Planning and Preparedness for Transport Accidents involving Radioactive Materials [13] shall be strictly followed.

7.6 Waste Disposal

7.6.1 Objectives:

The following objectives shall be the guiding factors in any waste disposal practice:

a) Future generations shall not be subjected to a risk higher than what is accepted by the present society;
b) There shall be no threat to the continued survival of other species; and
c) The predicted impacts of radioactive waste disposal practices on the environment shall be such that their interference on the future use of natural resources is as little as practicable.

7.6.2 Practices

In order to meet the objectives given above, the following practices shall be adopted [14]:

a) Any discharge of radioactive liquid or gaseous wastes to the environment shall be such that resultant collective dose shall be as low as reasonably achievable (ALARA), economic and social factors being taken into account;
b) Solid wastes and solidified wastes resulting from the operation of reactors and research laboratories are to be emplaced in near surface disposal facilities specifically constructed for the purpose.

Low and intermediate-level wastes containing trace quantities of alpha contamination from operation of fuel reprocessing units are also permitted in near surface disposal facility (Refer Annexure-5); and

c) High-level and alpha contaminated liquid wastes from fuel reprocessing facilities, which are initially stored in tanks, shall be vitrified and the solidified products shall be stored in near surface engineered storage facilities, with appropriate cooling and surveillance provisions for a minimum period of twenty years at the end of which the wastes shall be transferred to deep geological repositories. Disposal of high-level vitrified and cooled waste products and alpha wastes shall be in deep geological formations specifically chosen for the purpose.

Keeping in mind the above, the operating organisation should select an appropriate method of disposal of solid waste after considering the factors listed in 7.6.4.

7.6.3 Waste Categorisation and Mode of Disposal

Wastes generated in the decommissioning process should be segregated and categorised in the following five types according to final method of disposal or reuse.

a) High level waste (HLW): High-Level waste containing radioactivity having thermal power output above 2 kW/m^3 and or long lived radionuclides at concentrations exceeding the limiting concentrations for short-lived waste as given in c).
   - Disposal in deep geological repository.

b) Low and intermediate level waste - Long Lived (LILW-LL): Low and intermediate level wastes having thermal power output about 2 kW/m^3 containing long-lived α-emitting radionuclides at concentrations exceeding the limits for short-lived wastes as given in c).
   - Disposal in deep geological repository.

c) Low and intermediate level waste- Short Lived (LILW- SL): Low and intermediate level waste having thermal power output below 2 kW/m^3 and long-lived α-emitting radionuclides at concentration below 1500* Bq/g per individual package or 150 Bq/g average per consignment with or without short-lived activity.
   - Disposal in near surface disposal facility

* **Modified from the relationship 3700 Bq/g of alpha emitting radionuclides of half life > 5 yr=2.5 mSv/y to an individual.** (see annexure-5)

d) Low-level waste (LLW): Low level wastes with thermal power output below 2kW/m^3 and

   (i) activity levels exceeding 10 CL

disposal in NSD facility

(ii) activity above CL but not exceeding 10 CL

recycle or re-melt refers to modifying factor in Table A.4.1 of Annexure-1.

Exempt Waste (EW): Exempt waste containing activity levels at or below clearance levels which are based on an annual dose to members of the public of less than 0.01 mSv require neither radiological restrictions nor restrictions on equipment reuse.

Annexure-5 presents quantities of radionuclides that could be disposed off in near surface disposal facilities or deep geological repositories. Long-lived radionuclides and specific short-lived radionuclides posing radiation dose problems over long periods of time have been classified into distinct classes A, B and C with activity concentrations in increasing order. The table in Annexure 5 also presents packaging and structural stability requirements for these three classes.

Experience indicates that most of the radioactive waste will qualify for low and intermediate level waste suitable for disposal in near surface disposal facilities. Small quantities of high-level waste, with or without alpha contamination, will have to be stored in a retrievable fashion for disposal in deep geological repositories at a later date.

Section 3.4 of this manual contains criteria governing values of clearance level (CL). Keeping this in view, instrumentation shall be available to segregate (a), (b) and (c) from (d) and (e). This is particularly important for item (d) which usually represents a very large portion of the inactive waste and which goes for land filling.

7.6.4 Safety Considerations for the Disposal Facilities:

7.6.4.1 The disposal facilities shall be designed and constructed to limit movement of nuclides to biosphere such that the radiation detriment to the population is within the prescribed limits. A model study to demonstrate this ability shall be submitted to AERB.

7.6.4.2 Safety analysis of Solid Waste Management Facility (SWMF) shall be submitted to AERB for approval to demonstrate its suitability for decommissioning waste, in case the wastes are proposed to be disposed off in the existing SWMF. This should include total site burden, (total waste quantities and activities disposed during normal, off normal operating conditions, decommissioning waste etc.), waste package characteristics, engineered containment system, physico-chemical properties of the soil and geohydrological characteristics of the site. The detriment to the population assessed from an analytical model of radionuclide migration based on multi-barrier approach shall be within the prescribed limit. In case a fresh solid waste management site is chosen for decommissioning waste, the safety analysis of the new site shall also be carried out and submitted. The surveillance requirements of solid waste management facility are given in section 8.8.

7.6.4.3 The disposal operation and repository design shall take into account the radiation hazard due to gamma radiation to workers when containers are transported and transferred to the SWMF during normal and off-standard operating conditions.

7.6.4.4 A classification of radioactive wastes based on quantities of long lived/short lived activity is presented as Annexure-5. The quantities of radionuclides that could be disposed off in SWMF shall be below the concentrations indicated under Class-A wastes, without the packaging and structural stability requirements or under Class-B wastes with packaging, stability and physical dimension requirements.

8. HEALTH AND SAFETY CONSIDERATIONS

8.1 General

During decommissioning, a sizable number of persons may be employed to work in areas, which are contaminated and/or are likely to have high radiation levels. The dismantling and decontamination operations may generate radioactive aerosols and radioactive wastes. From health and safety considerations, the factors that need be considered during decommissioning have already been listed in section 6.2.5.1.

The health and safety programme for decommissioning should be specially tailored to suit factors listed in section 6.2.5.2 to ensure protection of the workers and the public.

8.2 Radiation Protection Procedures

Radiation protection procedures in a decommissioning program are very much similar to those followed in a reactor operation except that the radiation environment within active areas may keep on changing as decommissioning progresses. Because of this, the procedures need review at periodic intervals to ensure their effectiveness against the hazard present at any given time. These essentially include:

a) Control of radiation exposure to personnel;
b) Monitoring on-site and off-site which assists in demonstrating the effectiveness of decommissioning control procedures and integrity of containment; and
c) Radiation/Contamination monitoring of working environment/components & materials during the handling, packing, transportation and storage.

The guidelines given in the Manual [5] shall be followed during decommissioning phases also.

The responsible organisation shall provide adequate trained manpower and proven equipment for carrying out these functions.

8.3 Radiological Surveillance

On-site and off-site radiological surveillance are essential requirements of the health and safety programme during decommissioning. A pre-decommissioning on-site survey should be conducted to collect data towards preparing a detailed decommissioning plan (Section 6.4 and Annexure-2). This should include maximum and average radiation and contamination levels on systems, components and areas, the identification of radionuclides and measurement of their concentrations, and characterisation of contamination inside components and piping. Subsequent radiation and contamination surveys may be done, as appropriate, after the selection of a decontamination programme for detailed planning of activities during decommissioning. The extent and frequency of these periodic surveys should be spelt out in the decommissioning plan. The on-site surveys are intended to ensure adequacy of controls and to assist in mitigating radiological hazards to personnel.

Off-site radiation surveys provide indication of adequacy of control over radioactivity releases to the environment and provide data on the impact of decommissioning activities on the environment. Since experience indicates that off-site effects are minimal, there may not be a further need for extensive monitoring. However, the radionuclides of concern during the decommissioning phase may be different from those during the operating phase.

Hence, it is necessary to undertake a comprehensive off-site survey prior to undertaking decommissioning to provide a reference point for assessing environmental effects, if any, arising out of decommissioning. It is also essential to ensure that the dose limit criteria mentioned in Section 3.3.1 are met.

The handling, packing, storage and transport of radioactive materials should conform to AERB requirements on transport of radioactive substances. [12]

8.4 Criteria for Release of Materials from the Site

Materials and equipment released from the site for public use should conform to the clearance levels prescribed by AERB (Section 3.4 and Annexure-1).
Release of airborne and liquid wastes to the environment shall be within prescribed limits as per the revised Technical Specifications for the decommissioning phase.

Solid wastes of LILW-SL and LILW-LL ranges should conform to the criteria set forth in this manual (Section 7.6.3 and Annexure-1).

Annexure-6 gives a ready reference for release of radioactive material from the site in public domain or for waste disposal. (To be read in conjunction with Annexures 1 and 5)

Release of non-radioactive substances is governed by guidelines laid down by appropriate competent authorities.

8.5 Personnel Exposure Control Methods [9]

During on-site surveys, the aim should be to detect changes in levels of radiation, airborne activity or surface contamination. Such data could then be used towards effective control of occupational exposures. To check spread of contamination, change rooms or personal decontamination check points should be placed at locations between active and inactive areas. Respiratory protective equipment, special ventilated work tents, local exhausts, emergency showers, working under water, working on wetted surfaces and application of fixed paints on surfaces to contain loose contamination, etc. are also helpful. Provision for remote monitoring should exist in likely high radiation zones. Facilities for decontamination of vehicles waste containers and other equipment; dose recording and documentation procedure should be available. There should be a system of issuing radiation work permits.

8.6 Techniques for Reducing Occupational Exposure [9]

8.6.1 General

The principal methods for reducing occupational exposure consist of one or more of the following:

a) Reduction of radioactive sources; and
b) Reduction of dose rates.

8.6.2 Reduction of Radioactive Sources

This is primarily achieved by reducing or preventing the formation of activation products in the reactor and by preventing clean materials and areas from getting contaminated. The techniques include:

a) Material selection that helps to reduce or eliminate activation products such as ^{60}Co.;
b) Isolation of areas, equipment and systems which are susceptible to leaks or need frequent maintenance;
c) Isolation during dismantling or demolition to prevent spread of contamination;
d) System decontamination during plant operation to reduce contents of deposited radionuclides; and
e) Use of dismantling techniques, which avoid or reduce the production and spread of secondary contamination.

8.6.3 Reduction of Dose Rate

This is achieved by use of shielding, remote handling & robotics and by segregation of active & non-active systems/areas. Decontamination of select systems showing high levels of contamination may also reduce doses. Removal of the most contaminated equipment earlier and provision of local shielding placed at strategic positions will also reduce dose rate.

Techniques that allow decommissioning operations to be performed in shorter time periods should be adopted. Design changes that permit rapid disassembly of radioactive components (e.g. modular construction, improved access to equipment) should be considered. Mock-up of operations and improved decommissioning planning should be carried out to improve existing techniques or facilitate faster operation. Mock-up may also improve worker efficiency. Provision of localised shielding would also result in reduced exposures. Suitable fixtures should be designed for operation from a distance to reduce exposure.

8.7 Surveillance to ensure health and safety during decommissioning activities

8.7.1 Some of the practices used during decommissioning may produce adverse effects on the safety status of the plant. Examples are blockage of passages and stairways, increased fire hazards, exposure to hazardous or toxic chemicals, new unfamiliar electrical installations, poor lighting, ventilation and air conditioning, noise level increase, inadequate or excessive heating, reduction in working space due to new equipment being brought in etc. Such events should be watched for and appropriate corrective action should be taken.

8.7.2 The dose reduction techniques detailed in Section 8.6 should not jeopardise the plant safety systems, specifically in respect of the following:

a) Reliability, redundancy and diversity, physical separation;
b) Containment integrity, ability to withstand missile impact, high pressure and temperature, pipe whip etc.;
c) Integrity of seismically safe systems;
d) Routine operation, inspection and maintenance functions;
e) Accessibility to control panels, viewing positions and sampling stations;
f) Ability to handle, manoeuvre and lay-down equipment; and
g) Hatches, doorways, equipment loading capacities, safety margins etc.

8.7.3 Surveillance of components, systems and structures, in general, should include periodic checking to ensure operability of equipment, condition monitoring, preventive maintenance, updating of records as required for decommissioning.

8.7.4 There shall not be any compromise in the applicability of relevant design and engineering codes.

8.8 Surveillance of Solid Waste Management Facility (SWMF)

8.8.1 General

The responsible/operating organisation may use the existing SWMF or a new facility for the storage/disposal of low and intermediate level radioactive solid waste from decommissioning operation for near surface disposal subject to the factors listed in section 7.6.4. The environmental surveillance programme should be re-oriented as indicated in Section 8.3 and approved by AERB prior to reuse of the site.

The surveillance plans must be concerned with detecting the migration of unacceptable amounts of radioactive and other toxic materials, if any, from the site. Borewells for monitoring are intended for this purpose. Physical protection barriers prevent unauthorised access to the site. In addition to events that might reasonably be assumed to occur, such as breach in the engineered containment, leaching, etc. the plans must attempt to account for events of lower probability such as exceptionally heavy rain, flood, fire and inadvertent or intentional intrusion. In case of a new site, base line data must be established before the commencement of any radiological work on the site.

The following aspects should be covered in the surveillance plan of the solid waste management facility for the disposal of decommissioned waste.

8.8.2 During Operation and Short Term Surveillance:

a) keeping of records of the waste (volumes, types and activities of radionuclides) and their locations - corrected with benchmarks;
b) detection and monitoring of release of radionuclides if any to the environment from the SWMF; and
c) taking corrective action to ensure that long-term integrity of disposal system is maintained. During the period when the SWMF is operational, the operator should establish that the site is performing as predicted and that no unexpected release from the SWMF site has occurred.

Any significant changes to the above should be notified to AERB to allow a review of the site performance, if felt necessary.

8.8.3 Post-operational or Long Term Surveillance

Provision should be made for preventive maintenance and regular inspection of access control barrier in the post operational surveillance programme. The institutional control of the facility under the active control period and the passive control period should be clearly identified.

8.8.3.1 Active Control Period:

The following aspects need consideration:

a) Periodicity of sampling from monitoring positions with respect to soil samples;
b) Frequency of collection of vegetation samples and water samples from boreholes and nearby well or water body, if any;
c) Their analyses and interpretation of the results compared with the safety analysis report predictions and base line data;
d) Reinforcement measures, if found necessary, to ensure long term integrity of the entire disposal system; and
e) Adequate infrastructure support in terms of surveillance and security personnel.

8.8.3.2 Passive Control Period:

The following requirements should be met:

a) Physical barrier to prevent unauthorised human encroachment;
b) Preparation and implementation of periodic inspection and monitoring schedule;
c) Review of safety assessment.;
d) Upkeeping of topographical surface and drainage system of the site in good condition;
e) Prevention of intrusion of deep-rooted vegetation and habitation of deep burrowing animals; and
f) Checking that the rates of migration of radionuclides, if any, to the environment and groundwater are within the limits of safety assessment by taking appropriate measures.

8.9 Release of Site for Future Use

Procedures and tests should be specified for conforming that the hazard associated with unrestricted use of the site after the expiry of agreed institutional control period is acceptable.

In case permission for restricted use of the site is given prior to unrestricted use, certain activities such as digging, well drilling or earth moving operations, which might uncover the waste residues, should be restricted.

Although the term 'site', in general, means the area under the physical control of the operating organisation which includes the facility with associated building structures and also the solid waste management facility, the 'release of site' for restricted/unrestricted use shall be the 'entire site' or 'part of the site' with a well identified boundary with physical barrier for the purpose of 'release of the site' for future use.

9. QUALITY ASSURANCE

9.1 General

The operating organisation shall establish a quality assurance programme for decommissioning of a nuclear facility covering all activities, which may have an influence on decommissioning in a safe manner. The programme shall provide a systematic approach to all activities affecting safety and quality, including, where appropriate, written verification that each task has been performed in accordance with prescribed limits, regulations and approved procedures. The quality assurance programme shall be in conformance with the principles and objectives stated in the codes [15] [16]

9.2 Objective

The objective of the quality assurance programme is to ensure that all the mandatory requirements are met with regard to safety of the public, the workers and the protection of the environment.

9.3 Manual

A quality assurance manual for decommissioning shall be prepared by operating organisation for each nuclear facility based on the relevant guidelines [17]. It shall cover all aspects of decommissioning programme taking into consideration the requirements intended in the Technical Specification for decommissioning of the nuclear facility. Where applicable, it shall relate to the requirements of other statutory codes and standards. The manual shall be approved by the Competent Authority and shall be available in time to enable the intended functions to be performed in an orderly manner by qualified persons.

9.4 Aim of the Manual

The quality assurance manual should be prepared with the aim of ensuring the following:

a) The requirement of quality assurance for various decommissioning activities are recognised and verified for conformance;

b) Procedures for decommissioning activities are prepared, reviewed and approved, including revisions resulting from major changes; and

c) All important information relevant to decommissioning shall be adequately documented, stored and made retrievable for future reference upto 30 years after the site is released for unrestricted use.

9.5 Administrative Control Prior to Start of Decommissioning

For the purpose of administrative control, the following shall be established prior to start of decommissioning;

a) Clear line of responsibility and authority shall be established;
b) All applicable approved procedures and instructions pertaining to decommissioning shall be available; and
c) Necessary training to the staff in decommissioning is given.

9.6 Activities Prior to Approved Decommissioning Procedures:

The following activities should be carried out in accordance with the approved decommissioning procedures:

a) Identification, handling and control of radioactive materials;
b) Checking of equipment and tools needed for decommissioning for their proper function and operation;
c) Inspection of important systems, structures and components for their integrity; and
d) Carrying out required surveillance for above activities.

9.7 Accounting of Radioactivity

Since decommissioning of a nuclear facility involves handling of radioactive material on a large scale, the quality assurance programme should take into consideration the following aspects for proper accounting of radioactivity:

All information and records relating to radioactivity in the nuclear facility are collected and documented prior to decommissioning;

For decommissioning upto restricted release[7] of the site, the records pertaining to location, configuration, quantities, and types of radioactivity remaining at the site during prolonged period are updated and properly accounted for; and

For subsequent decommissioning upto unrestricted release of the site, all the radioactive materials that were present at site at the commencement of decommissioning are properly accounted for, their ultimate destination identified along with their residual activity and confirmed before releasing the facility for unrestricted use.

[7] The release of materials, equipment, buildings or the site which is restricted by AERB.

10. ORGANISATION FOR DECOMMISSIONING

10.1 General

For efficient supervision of the decommissioning programme, the responsible organisation should set up at its headquarters, a Decommissioning Cell at the earliest. This may handle matters pertaining to decommissioning policies and strategies, contracts and materials, health and safety, quality assurance, waste management, documentation and records, accounts and finance and supporting administrative services.

Decommissioning activities of a particular facility should be carried out by setting up a site organisation (or cell) five years before starting of decommissioning

Till the release of the site either for unrestricted public use or for use by responsible organisation as authorised by AERB, the site cell should continue to function.

Following release of the site either for unrestricted public use or for use by responsible organisation, the site cell may be wound up.

After final shutdown of a facility, if decommissioning is taken up immediately for its completion upto unrestricted release of the site, the site cell may be a continuation of the operating organisation with changes in personnel as required.

After the completion of preparatory steps for decommissioning, if the subsequent decommissioning is not taken up immediately, the site cell may be limited to essential staff required for security and surveillance. Subsequently for completion of decommissioning upto unrestricted release of site, augmentation of site cell should be done by the headquarters cell.

A typical decommissioning organisation is indicated in Annexure-7.

10.2 Responsibilities

10.2.1 The Headquarters Cell

The Headquarters Cell should have the following responsibilities:

a) Preparation of the decommissioning plan and its submittal to AERB for securing its approval;

b) Liaison with AERB, environmental monitoring agencies, if any, and statutory bodies at national/state level regarding release of chemical effluents, suspended particulate matter etc. to the environment;

c) Execution of the decommissioning plan and preparation and submittal of the final decommissioning report;

d) Management and co-ordination for the removal of recoverable radioactive materials like fuel, process fluids etc. as applicable from the facility and its safe despatch out of the site;

e) Compliance by site cell ensuring the following:

   i) exposure control of decommissioning personnel including overexposure investigations;

   ii) safe disposal of radioactive wastes;

   iii) release of radioactive materials below prescribed levels for recycling; and

   iv) release of materials below CL for unrestricted use.

f) Maintenance and updating of documents on surveillance including drawings;

g) Provision of resources such as financing, trained manpower, etc.;

h) R&D activities relating to development and testing of various facilities/mechanisms for decontamination and dismantling.

10.2.2 The Site Cell

The Site Cell should be assigned with the following responsibilities:

a) Implementation of the decommissioning activities at site as per approved decommissioning plan;

b) Preparation/submission of periodic progress reports on execution of decommissioning activities including major deviations and constraints encountered;

c) The final radiation survey after completing decommissioning; and

d) Assistance to headquarters cell in preparing the final decommissioning report including the manner in which how the decommissioning plan objectives were achieved together with supporting data.

11. DOCUMENTATION AND REPORTING

11.1 During Design, Construction, Commissioning and Operation Phases

During design, construction, commissioning and operational phases of a nuclear facility extensive amount of information would have been generated and recorded appropriately. Some of the data could be valuable to assist the decommissioning personnel to plan their program effectively. Since a large part of this data is not pertinent to decommissioning it would be necessary to select the information needed for decommissioning and preserve this in an easily retrievable form which is at the same time cost effective. This task should be an on-going process during operation phase. [8, 11]

These include, inter alia:

a) all the relevant details of design basis/calculations and constructional sequences / methods used;
b) material test certificates and analysis to aid estimation of activation products;
c) as-built construction drawings;
d) photographs & video recordings, if any, taken during construction and installation;
e) data on material handling methods and equipment used during installation and maintenance, which could be of value during decommissioning;
f) unusual occurrences during operation which may have an effect on decommissioning procedures;
g) radiation and contamination level maps as per the periodic radiation survey.
h) Scale model of the facility; and
i) accounting of the spent/fresh fuel till despatch of all fuel to off-site location.

11.2 Final Planning of Decommissioning

11.2.1 After deciding on final shut down of the facility, the operating/responsible organisation should intimate AERB about the same. At this point of time, the decommissioning plan would have already been prepared by the operating/ responsible organisation and submitted to AERB (section 6.4). Consistent with the provisions of 3.2 and 4.1 the operating organisation should apply for modification of the facility. Technical Specifications for operation into Technical Specifications for Decommissioning.

11.2.2 The operating and surveillance procedures of the systems to be retained in service during decommissioning phases should be spelt out along with the reports for surveillance of the same.

11.2.3 Healthiness of equipment to be used in decommissioning such as cranes, crawlers and other lifting tackles and their test report to comply with relevant provisions of Atomic Energy (Factories) Rules should be documented. [4]

11.2.4 Details of various facilities/mechanisms developed during operation phase and to be employed for decontamination and dismantling during decommissioning should be available.

11.3 During Decommissioning Periods

11.3.1 The operating/responsible organisation shall keep an up- to-date record of the decommissioning activities completed, data on personnel exposure (individual and collective), record of radioactive wastes under temporary storage, radioactive effluents released and wastes finally disposed.

11.3.2 Reports on following should be maintained:

a) satisfactory functioning of radiological monitoring instruments, their calibration and frequency of testing;

b) results of environmental monitoring and any modification in the monitoring and frequency of monitoring after start of decommissioning with prior approval of AERB;

c) demonstration of compliance with national, state and local government legislations on environmental control; and

d) fire detection and fire fighting provisions of the facility and on their testing.

11.3.3 Reports on decommissioning activities and experience shall be sent to AERB at regular intervals to enable it to monitor the on-going decommissioning process in a timely way.

In addition, any safety related unusual occurrence during decommissioning shall be promptly reported to SARCOP/AERB.

11.4 On Completing Final Decommissioning

11.4.1 A final decommissioning report (refer Annexure-8) shall be prepared and submitted to AERB at the conclusion of the decommissioning.

11.4.2 Suitable arrangements shall be made for storage and retrieval of relevant decommissioning records for any reference, for 30 years after the site is released for unrestricted use.

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ANNEXURE -1

Criteria Governing Dose Limits for Clearance Levels (CL), Shallow Land Burial (SLB) and Long Term Waste Repositories

INTRODUCTION

During the preparation of the AERB Safety Guide on Decommissioning of Nuclear Facilities, a need was felt to develop a few criteria pertaining to radiological protection aspects of decommissioning. These are (a) radioactivity limits for articles/materials released for use by members of the public - the so called values of Below Regulatory Concern (BRC), (b) dose apportionment values for near surface facility facilities, and (c) dose limits for disposal of radioactive wastes on a long-term basis. Recently IAEA, as a part of its Safety series, has studied in detail the Clearance Levels from the point of view of regulatory approach and has given a set of recommended values. These values have been adopted in this document.

Part A: Limits on radioactivity in materials released for use by members of the public (Clearance Levels) (CL).

A.1 Large quantities of scrap and waste materials such as steel and concrete debris containing very low levels of radionuclides are generated during decommissioning of nuclear facilities. Steel can be recycled because of its economic value. Concrete debris may be used as land fill or be simply discarded as waste.

In recycling steel components, some may be put to direct use and some after appropriate metallurgical treatment with or without dilution by uncontaminated steel.

A.2 In the development of the criteria for the clearance levels, two steps are involved: (a) to lay down the basic dose criteria which is exempt from regulatory control, and (b) using these values to develop mass activity and surface activity concentrations of radionuclides for practical use.

A.3 Basic Dose Criteria

A.3.1 Existing Criteria Elsewhere

A gleaning of published literature on the clearance levels (known earlier as BRC values) proposed outside India has yielded the following information:

1.0 USNRC Criteria (1)

a) a dose limit, attributable to the exempt practice of 0.1 mSv/y (100 μSv/y) to an individual belonging to the critical group

b) a collective dose, which should be ALARA and which in order to qualify for regulatory exemption, shall be less than 10 man-Sv per year. In calculating the collective dose, individual dose rates less than 1 µSv/y are disregarded.

2.0 Values suggested by IAEA (2)

2.1 IAEA has recently developed the following BRC values

a) a dose upper bound of 10 µSv/y to an individual belonging to the critical group

b) a collective dose limit of 1 man-Sv per year.

In both cases above, values indicated are applicable to each exempt practice.

2.2 In the recent revision of Basic Safety Standards (3), IAEA has adopted the following values:

a) the effective dose to be incurred by any member of the public due to the exempted practice or source of the public due to the exempted practice or source is of the order of 10µSv or less in a year; and

b) the collective effective dose from one year of performance of the practice is no more than 1 man-Sv

A.4 Criteria Adopted and Derived Values

A.4.1 Consistent with the values suggested by the Basic Safety Standards (3), the committee suggest that the following values may be acceptable:

a) the effective dose to an individual from an exempted practice or source shall not be higher than 10µSv per year; and

b) the collective dose from the practice so exempted shall not be higher than one man-Sv in an year of practice.

A.4.2 The Committee believes that in actual practice there may be practices, which may be treated in actual situations as unconditionally exempt i.e. cleared unconditionally without the need for regulatory control and a few practices where some regulatory control may be exercised. Pending a detailed study of the practices that are likely to arise in future needing regulatory control and use of materials released from decommissioning and other similar operations, the Committee believes that for the time being the modifying factors have to be applied.

Since the modifying factors suggested elsewhere appear to have merit in use, the Committee has decided to adopt them also in this document.

A.4.3 Derived Values

A Committee appointed by AERB undertook the task of deriving the clearance levels for steel and concrete for release in the public domain (4). Based on the mode of use of the released material, a set of modifying factors was also suggested. A modifying factor of 0.1 was suggested for unrestricted release of materials to garbage and municipal dumps and to uses such as landfill. The Committee on Decommissioning finds that the dose resulting from clearance levels suggested, together with the modifying factor for unrestricted use by the public would be less than 0.01 mSv/y (10 μSv/y). Since this dose would be below the dose value suggested in para A.4.1 and also since the IAEA has suggested the same dose value, the Committee has decided to endorse the IAEA values of clearance levels.

The clearance levels and the modifying factors adopted are given in Table A.4.1.

Table A.4.1

Clearance Levels for important radionuclides relevant to decommissioning operations

Nuclide	Clearance Level in Bq/g	Modifying factors
^{3}H	3×10^{4}	
^{14}C	3000	
^{60}Co	3	1. Unrestricted release x 0.1
^{63}Ni	3×10^{4}	2. Restricted release to x 1.0 garbage landfill,
^{94}Nb	3	municipal dumps
^{238}U	3	3. Release for public use x 10 with specific clearance from competent authority
^{239}Pu	3	
^{99m}Tc	300	
^{90}Sr	30	
^{137}Cs	3	

Part B: Dose Apportionment for Near Surface Disposal Facilities (NSD)

B.1 Values of dose limits for NSD facilities adopted in different countries have varied widely. France has adopted 1 mSv/y, USA 250 μSv/y, UK 500 μSv/y for effluent discharges and Czechoslovakia 100 μSv/y. In the Indian DAE programme, the Health Physics Division of BARC has suggested a site burden of 50 μSv per year for each site through the terrestrial route (5). A discussion paper on waste management prepared in BARC a few years ago had suggested an apportionment of 100 μSv/y) for each site. Taking into account the factors considered in Parts A and C of this presentation, it is considered appropriate to have a value of 100 μSv/y per year as the dose limit for each site. The intervention level for a probabilistic event such as human intrusion is 5 mSv.

B.2 The NSD facilities will be designed to receive LILW-LL and LILW-SL, which may entail long-lived and/or short-lived radionuclides including alpha emitters. Annexure-5 provides a classification based on concentrations of long-lived and short-lived radionuclide supplemented by other criteria that will determine the mode of disposal either to NSD or retrievable storage facilities.

The period of institutional control for NSD sites is 100 years.

Part C: Dose Apportionment for Long Term Disposal of Radioactive Wastes

C.1 A survey of published literature available on the subject yields values of dose limits for long term disposal of radioactive wastes as summarised in Table C.1.1. Column 3 of Table C.1.1 indicates the basis used in deriving these values. To compare these, a common basis has to be established. Column 4 of Table C.1.1 presents individual risks for the values found in Column 2 of the table, using the new ICRP risk co-efficient of $5x10^{-2}$ Sv^{-1} for cancer fatalities. (6)

ICRP has suggested a safety goal of $10^{-5}y^{-1}$ for long-term waste management (7). As ICRP introduced the new risk co-efficient much later than ICRP 46, the dose that would correspond to a risk of $10^{-5}y^{-1}$ was 1 mSv/y. The new risk co-efficient would make 10^{-5}. y^{-1} equivalent to 0.2 mSv/y.

In this criterion, the suggested dose limit is 0.1 mSv/y. This implies the risk associated with NSD facility usage will be lower than what ICRP has suggested.

Table C.1.1

Dose Values used in different countries for long term disposal of radioactive wastes

Country	Dose limit in force $mSv.y^{-1}$	Bases for Deriving the dose limit	Individual risk in terms of ICRP's new risk coefficient
Canada	0.05	$2x10^{-2}$ as total risk 10^{-6}/y as acceptable	2.5×10^{-6}
Argentina	0.10	Lethality risk 10^{-6}/y	5×10^{-6}
Italy	0.10	Not specified	5×10^{-6}
Switzerland	0.10	-do-	5×10^{-6}
FRG	0.30	-do-	1.5×10^{-5}
USA	0.25	-do-	1.25×10^{-5}

Analytical models used for predicting doses from long term repositories have indicated the need for time delays between actual disposal and the appearance of the radionuclides in the environment. Delays of not less than 1000 years in waste conditioning and packaging and 10^4 years in geological barriers have been found required for meeting the source upper bound values. Thus methods of waste packaging, the backfill used and the geological barrier details need to be carefully worked out and analysed in order to meet the criteria. Such details are beyond the scope of this presentation.

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ANNEXURE – 2

DECOMMISSIONING PLAN (Section 5.1, 7.4)

Information to be provided by Responsible/Operating Organisation, while applying for decommissioning to AERB

1.0 FACILITY DETAILS - AT THE TIME OF FINAL SHUT DOWN

1.1 Name and address of the Facility.
1.2 Present Regulatory consent issued.
1.3 Proposed modification of Regulatory consent for decommissioning.
1.4 Description of systems and equipment.
1.5 Estimated inventory of material and their radioactivity, furnishing the calculation methods and measurement used.
1.6 Unusual occurrences related to spread of activity.

2.0 DECOMMISSIONING STRATEGY

2.1 Decommissioning objectives.
2.2 Decommissioning strategy considered with time periods to meet the objectives and their justification.
2.3 Types and volume of radioactive waste anticipated and routes for disposal in the options considered.
2.4 Dose estimates for the options considered.
2.5 Cost estimates for the options considered.
2.6 Method of funding the decommissioning.
2.7 Safety Analysis of the decommissioning strategy considered.

3.0 DECOMMISSIONING ORGANISATION AND PROJECT MANAGEMENT

3.1 Structure of organisation.
3.2 Function and responsibilities, minimum qualifications, training and experience.
3.4 Assistance from outside organisations including contract works

This should include details such as:

Identification of activities to be executed
Commitment to comply with relevant regulatory provisions
Training of contractor's personnel and their records

3.5 Site security with reference to access control and material movement.
3.6 Project review and monitoring methods.
3.7 Reporting and record keeping.

4.0 DECOMMISSIONING ACTIVITIES

4.1 Estimated levels of radioactivity at the time of final shut down and their expected levels at different time periods during decommissioning.

4.2 Requirement of the utilities/service systems and equipment and their surveillance at different time periods of decommissioning.

4.3 Techniques and procedures to be used for decontamination, dismantling and waste management based on experience/feed back from construction, commissioning and operation phases.

4.4 Requirement/development of robotics/remote handling tools/systems for various decommissioning jobs.

4.5 Revised technical specification as applicable to decommissioning phase.

4.6 Detailed decommissioning activity sequence diagram with time schedule.

5.0 QUALITY ASSURANCE PROGRAMME APPLICABLE TO DECOMMISSIONING

5.1 Preparation of quality assurance manual applicable to decommissioning of the facility, ensuring that all activities pertaining to decommissioning are carried out in a safe manner.

6.0 SAFETY ANALYSIS

6.1 Availability of safety systems and equipment such as containment, ventilation system, radiation monitoring instruments etc.

6.2 Safety assessment of probable accidents during decommissioning.

6.3 Preparedness for management of site emergency.

7.0 RADIOLOGICAL PROTECTION PROGRAMME

7.1 Radiological history of the facility

7.1.1 Identification of systems, equipment, areas of the site that might have been inaccessible during the plant's life-time and may be excessively contaminated.

7.1.2 Radiation survey and mapping of contaminated systems, structures and components.

7.2 Management's approach to ALARA

7.3 Implementation of occupational radiation protection programme as stated below:

(a) Occupational radiation protection procedures,

(b) Monitoring and Survey instruments,

(c) Effluent analysis and personnel dosimetry policy methods,

(d) Contamination control programme

7.4 Potential sources -

Identification of potential sources of radiation or contamination exposure to workers or to members of the public that are likely to be generated during decommissioning activities and their control.

7.5 Contractor's personnel -

Radiation protection policies for safety of contractor's personnel while working in restricted areas and the method of implementing those policies.

8.0 RADIOACTIVE WASTE MANAGEMENT

8.1 Process, systems to be used for handling, storing and disposal of radioactive wastes.

8.2 Estimation of waste generation during decommissioning stages with details such as volume, radionuclide concentration, waste forms, classifications etc.

8.3 Precautions to be taken to avoid contamination/mix-up of large quantity of inactive material with active material, while taking up decontamination/dismantling.

8:4 Details regarding interim/temporary storage of wastes including quantities, expected length of storage, location of storage, radiation levels at accessible places and method of positive control and accounting.
In case of landfill, the criteria for unrestricted release would be met.

9.0 PLANNED FINAL RADIATION SURVEY

9.1 Description of survey procedure

9.2 Proposed method of survey to ensure all structures, systems, equipment and ground are included and sufficient data is collected for meaningful survey.

9.3 Description and data on background radiation.

9.4 Type specification and operating conditions of the instrument to be used.

9.5 Plan for reviewing, analysing and auditing by AERB.

9.6 Expected radiation and contamination levels towards release of facility for unrestricted use and justification, if regulatory criteria are not likely to be met with.

ANNEXURES - 3A, 3B & 3C

MAJOR DECOMMISSIONING ACTIVTIES AS APPLICABLE TO VARIOUS NUCLEAR FACILITIES

These annexures attempt to list major activities of decommissioning relevant to various nuclear facilities and they are only indicative.

The activities list are as per chapter 5 and they will depend on the factors listed in section 7.2.

The activities related to documentation and records are separately covered in chapter 12.

ANNEXURE - 3 A

PREPARATORY PHASE FOR DECOMMISSIONING

Y - Generally applicable X - May or may not be applicable
N - Generally not applicable

Nuclear Facilities →	REACTOR		FUEL CYCLE PLANTS					RELEVANT SECTION IN THE MAIN TEXT
Major Activities of Decommissionings	Power Plant	Research Reactors	Fuel Reprocessing Plant	Waste Management Plant	Uranium Recovery & Milling Plant	Fuel Fabrication Facilities (Active/ Inactive)	Rad. Lab. including PIE* Facility	
Transfer of fuel, as practical	Y	Y	Y	N	Y	Y	X	5.2.1
Removal of process radioactive materials like coolant, moderator, process fluids etc.	Y	Y	X	X	X	N	N	5.2.2
Removal of easily accessible and removable components, Systems and structures	Y	Y	Y	Y	Y	Y	Y	5.2.2
Stabilisation and sealing of systems containing radioactive materials.	Y	Y	Y	X	X	X	X	5.2.3
Surveillance of components, systems And structures	Y	Y	Y	Y	X	X	X	5.2.4
Maintaining the contamination barrier and its surveillance	Y	Y	Y	Y	X	X	X	5.2.5
Containment/ Confinement structures	Y	Y		X	N	X	X	5.2.6
Access control	Y	Y		Y	Y	Y	Y	5.2.7
Operability of required utilities including monitoring systems	Y	Y	Y	Y	Y	Y	Y	5.2.8

* PIE - Post Irradiation Examination

ANNEXURE - 3 B

DECOMMISSIONING PHASE FOR RESTRICTED SITE RELEASE

Y - Generally applicable X - May or may not be applicable
N - Generally not applicable

Nuclear Facilities →	REACTOR		FUEL CYCLE PLANTS					RELEVANT SECTION IN THE MAIN TEXT
Major Activities of Decommissioning	Power Plant	Research Reactors	Fuel Reprocessing Plant	Waste Management Plant	Uranium Recovery & Milling Plant	Fuel Fabrication Facilities (Active/ Inactive)	Rad Lab including PIE* Facility	
Transfer of fuel the plant boundary, if not done earlier	Y	X	X	N	N	N	N	5.3.1
Decontamination and/or dismantling of active parts and areas and their storage for further decay/disposal as radioactive waste/released for restricted or unrestricted use as authorised by AERB	Y	Y	Y	Y	X	X	X	5.3.2
Sealing of remaining radioactive parts of the plant by physical means for further radioactive decay under surveillance.	Y	Y	Y	Y	N	X	X	5.3.3
Reduction of the contamination barrier	Y	Y	Y	X	N	X	X	5.3.4
Modification of containment building & nuclear ventilation system	Y	Y	X	X	N	X	X	5.3.5
Continuation of surveillance for radiological safety, structural integrity and operability of remaining utilities.	Y	Y	X	X	X	X	X	5.3.6
Release of materials and equipment with radioactivity at clearance levels for unrestricted use.	Y	Y	Y	Y	Y	Y	Y	5.5.1

* PIE - Post Irradiation Examination

ANNEXURE - 3 C

DECOMMISSIONING PHASE FOR UNRESTRICTED SITE RELEASE

Y - Generally applicable X - May or may not be applicable

N - Generally not applicable

Nuclear Facilities →	REACTOR		FUEL CYCLE PLANTS					RELEVANT SECTION IN THE MAIN TEXT
Major Activities of Decommissionings	Power Plant	Research Reactors	Fuel Reprocessing Plant	Waste Management Plant	Uranium Recovery & Milling Plant	Fuel Fabrication Facilities (Active/ Inactive)	Rad Lab. including PIE* Facility	
Removal of all radioactive parts of the plant								5.4.1
(a) for unrestricted use at Clearance level	Y	Y	Y	Y	Y	Y	Y	
(b) to solid waste management facility.	Y	Y	Y	Y	Y	Y	Y	
Final radiation Survey	Y	Y	Y	Y	Y	Y	Y	5.4.2

* PIE - Post Irradiation Examination

ANNEXURE – 4

Details of different types of radioactive solid and liquid waste in decommissioning of boiling water reactors (BWR), pressurised heavy water reactors (PHWR) and other nuclear facilities

NUCLEAR POWER PLANTS

A detailed assessment regarding sizes, volumes and categories of waste, radiochemical characterisation and activity levels of different types of waste namely primary decommissioning waste and operational decommissioning waste should be done. Assessment of facilities required for their handling, treatment, conditioning, packaging, transportation and disposal is also required to be done.

1.1 Primary Decommissioning Waste

These are mostly active components from reactor system, rad waste system, turbine and other auxiliary systems consisting mainly of metallic components and contaminated concrete structures (biological shield) etc. These wastes will be generated during dismantling operation during preparatory steps for decommissioning. After decontamination in preparatory steps for decommissioning, the radiation levels of most of the equipment, particularly the reactor externals will fall to the levels presently permitted for disposal in RCC Vaults/Trenches i.e. less than 0.5 Sv/h. As far as possible, most of the materials from reactor externals should be cut to suitable size which can be packed and transported in disposable standard mild steel drums (200 litre capacity) in reusable shielded concrete/lead casks. Wherever necessary, immobilisation with cement concrete should be done before transportation. In certain cases, cutting may not be possible/desirable. These equipment such as heat exchangers, pumps etc. may have to be transported in specially designed cask and disposed in especially designed disposal facilities. The reactor vessel can be disposed as a whole in one piece in a specially built vault or cut into suitable sizes. In the latter case, remote cutting tools and techniques may be required. Arrangements for placing the pieces in suitable containers and their transportation in shielded casks needs to be worked out. Disposal in tile holes for this waste may also be considered.

1.2 Operational Decommissioning Waste

Operational decommissioning waste will be generated in all the three phases of decommissioning. There will be sizable quantities of wastes in the form of solids and liquids. These wastes are likely to consist of the following

Operational Solid Wastes

A) Assorted Waste
Contaminated concrete chips, cellulosic materials (woods, cotton, mops etc.), rubber and plastics.

B) Higher Active Solids

[Spent resins, filter sludges, filters from ventilation system, fuel cladding hulls etc.]

Operational Liquid Wastes

Liquid from draining and flushing of active systems, ion exchange regenerants, spent decontamination solutions and washings, slurries from reactor building, turbine building dry well, rad waste building sumps, etc. constitute operational decommissioning wastes.

The details of the activities carried out from the point of view of generation of waste during decommissioning are as follows:

(i) Preparatory steps

The waste will be generated in the initial period of 5 to 10 years involving important activities such as defueling, spent fuel cooling, removal of easily accessible process radioactive materials (moderator, coolant, process streams etc.) and plant components, draining and flushing of the systems including decontamination of primary systems etc.

(ii) Prompt decommissioning

Major portion of dismantling will be done during this stage, followed by decontamination of easily removable parts of the reactor. This is aimed at reducing the contamination barrier to a minimum. Large quantities of solid and liquid wastes will be generated during this stage.

(iii) Delayed decommissioning

After completion of earlier phases of decommissioning (which is to be decided by the operating organisation and outlined in the decommissioning plan), dismantling of the remaining active systems would be taken up. In this phase, major portion of equipment structural, concrete etc. in which activity is still remaining will be removed. The waste generated in this stage include low level decontamination solutions and dismantled active system and components of assorted nature.

Other wastes, namely, filter sludges and spent ion exchangers from clean up systems of spent fuel, filters from ventilation system etc., will be generated until all systems including spent fuel storage bay is decommissioned and dismantled.

2. OTHER FACILITIES:

2.1 Radioactive waste will be generated in the decommissioning of other nuclear facilities such as reprocessing plants, uranium mining and milling facilities, fuel fabrication plants, storage facilities for waste and spent fuel and also during decommissioning of a facility after an accident. For all facilities, a well developed strategy, good training, thorough planning and good documentation are necessary to carry out the decommissioning in a safe, timely and economic manner. The waste quantities in appropriate categories need to be estimated and its storage/disposal scheme worked out.

2.2 Decommissioning of reprocessing facilities will require extensive use of shielding, remotely operated equipment, containment and respiratory protection equipment because of high radiation field and significant alpha contamination in many parts of the plant.

2.3 Plants handling transuranics may contain significant concentration of alpha activity and low level gamma activity. Deferred dismantling of plants like Uranium and Thorium mining/milling, fuel fabrication plants and abandoned radium processing facilities does not result in any significant reduction in occupational exposures because of long half lives of contaminants. Also, such deferment could result in increased spread of contamination if plant is allowed to deteriorate after shutdown. The major problem in these types of facilities is the management of very large volumes of waste. Wastes containing transuranics should be classified as per Annexure-5 for further management.

3. DECOMMISSIONING OF SOLID WASTE MANAGEMENT FACILITY (SWMF):

A near surface facility for the management of low and intermediate level solid/solidified waste (having limited fission products activity of ^{137}Cs and ^{90}Sr and very low transuranics (TRU waste) is being practised at all nuclear facilities. The SWMF is generally within the exclusion zone of the nuclear facility. An active and passive institutional control for the desired period of isolation shall have to be planned by the licensee or his representative. A detailed plan of active and passive control with complete documentation of waste inventory at SWMF and stages of decommissioning or complete decommissioning of SWMF shall be worked out by the operating organisation and submitted to AERB for approval.

ANNEXURE - 5

Maximum Concentrations of Radionuclide permissible for Disposal in Near Surface Disposal (NSD) Facility

Isotopes 1	2	3	4	5
^{14}C				120 GBq/m^3
^{14}C *				1200 "
^{59}Ni *				3250 "
^{94}Nb				3 "
^{99}Tc				45 "
^{129}I				1.2 "
Alpha emitting transuranics of $T_{1/2} > 5$ years				1500 Bq/g
^{241}Pu				50 kBq/g
^{242}Cm				300 "
Total of all radionuclides of $T_{1/2} < 5$ yr.	10 TBq/m^3	**		**
^{3}H	0.6 "	**		**
^{60}Co	10.0 "		**	**
^{63}Ni	0.05 "	1 TBq/m^3	10 TBq/m^3	
^{63}Ni *	0.5 "	10 "	100 "	
^{90}Sr	0.6 GBq/m^3	22 "	100 "	
^{137}Cs	15 "	0.6 "	70 "	

Modified from 10 CFR 61 in activated metal

** No limits given for Class B and C wastes.

Note 1:

Radioactive Wastes are classified based on type and quantity of radionuclides present.

Class A: Wastes are those which contain

i) None of the isotopes listed in the Table.

and/or

ii) Less than or equal to 0.1 times of the radionuclides concentration listed in Column 5.

and /or

iii) Less than or equal to radionuclides concentrations listed in Column 2.

Class B: Wastes are those which contain radionuclides whose concentration exceed that in column 2 but does not exceed values in Column 3.

Class C: Wastes are those which contain

i) Radionuclides whose concentration exceed that in Column 3 but less than or equal to concentration listed in Column 4. and/or

ii) Radionuclides concentration exceeding 0.1 times and upto the concentrations listed in column 5

Wastes containing excess of values of Column 4 and/or of Column 5 are not suitable for NSD.

Note 2:

Class B and Class C waste form/packages must be structurally stable and must maintain physical dimension and form under repository conditions over a period of 300 years and institutional control of the site upto 100 years. While nuclide contents of Class A and B will decay to innocuous levels within the control period, Class C wastes could still present a hazard after the 100 year period and would require deeper burial or the installation of intrusion barriers[8] having an effective life of 500 years or more.

[8] The components of a disposal system designed to prevent inadvertent access to the waste by man, animals and plants.

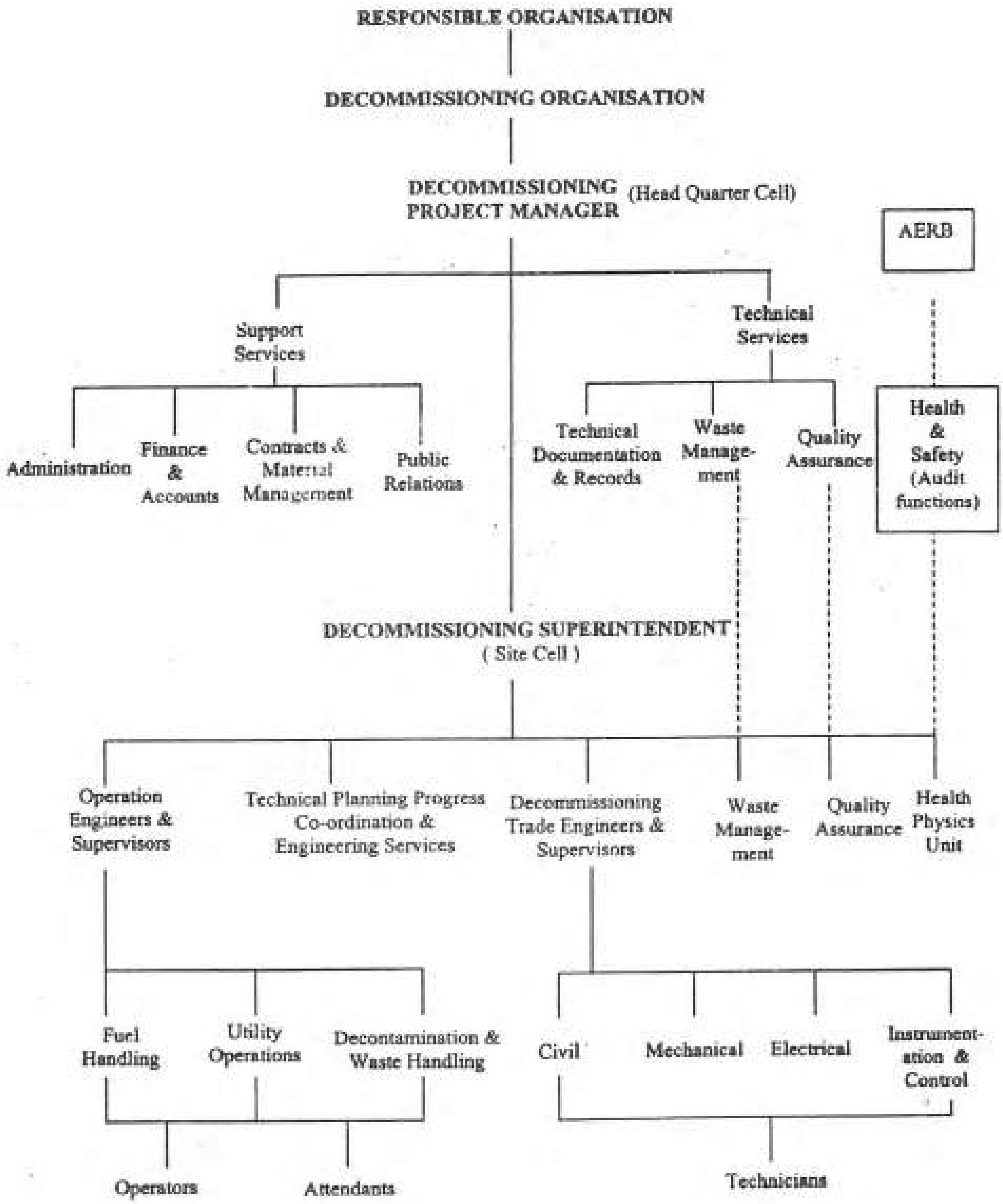
ANNEXURE-6

Radionuclide Concentrations for Release of Materials in Public Domain or for Waste Disposal

(Integrated from Table A.4.1 of Annexure-1 and Annexure-5)

Nuclide	Unrestricted release (exempt waste) (Bq/g)	Restricted release (garbage landfill) (Bq/g)	Restricted release with clearance from competent authority (Bq/g)	Near Surface Disposal			Deep Geological Repositories
				Class A	Class B	Class C	
^{14}C	-	-	-	≤12 GBqm^{-3}	-	≥12 GBqm^{-3} ≤120 GBqm^{-3}	>120 GBqm^{-3}
^{14}C	-	-	-	≤ 120 GBqm^{-3}	-	≥ 120 GBqm^{-3}≤120 GBqm^{-3}	>120 GBqm^{-3}
^{59}Ni	-	-	-	≤325 GBqm^{-3}	-	>325 GBqm^{-3}<3250 GBqm^{-3}	>3250 GBqm^{-3}
^{94}Nb	<0.3	<3.0	<30	≤0.3 GBqm^{-3}	-	>0.3 GBqm^{-3} ≤3 GBqm^{-3}	>3 GBqm^{-3}
^{99}Tc	<30	<300	3x10^{3}	≤4.5 GBqm^{-3}	-	>4.5 GBqm^{-3} ≤45 GBqm^{-3}	>45 GBqm^{-3}
^{129}I	-	-	-	≤0.12GBqm^{-3}	-	>0.12 GBqm^{-3} ≤1.2 GBqm^{-3}	>1.2 GBqm^{-3}
^{239}Pu	<0.3	<3.0	<30	≤150 Bq/g	-	>150 Bq/g ≤1500 Bq/g	>1500 Bq/g
^{234}U	<0.3	<3.0	<30	≤150 Bq/g	-	>150 Bq/g ≤1500 Bq/g	>1500 Bq/g
^{3}H	<3x10^{3}	<3x10^{4}	<3x10^{5}	≤0.6 TBqm^{-3}	NA	NA	-
^{60}Co	<0.3	<3.0	<30	≤10 TBqm^{-3}	NA	NA	-
^{63}Ni	<3x10^{3}	<3x10^{4}	<3x10^{5}	≤0.05 TBqm^{-3}	>0.05 TBqm^{-3} ≤1.0 TBqm^{-3}	1.0 TBqm^{-3} ≤10 TBqm^{-3}	>10 TBqm^{-3}
$^{63*}Ni$	-	-	-	≤0.5 TBqm^{-3}	>0.5 TBqm^{-3} ≤10 TBqm^{-3}	>10 TBqm^{-3} ≤100 TBqm^{-3}	>100 TBqm^{-3}
^{90}Sr	<3	<30	<300	≤0.6 GBqm^{-3}	>0.6 GBqm^{-3} ≤22 TBqm^{-3}	>22 TBqm^{-3} ≤100 TBqm^{-3}	>100 TBqm^{-3}
^{137}Cs	<0.3	<3	<30	≤15 GBqm^{-3}	>15 GBqm^{-3} ≤0.6 TBqm^{-3}	>0.6 TBqm^{-3} ≤70 TBqm^{-3}	>70 TBqm^{-3}
Total of All Nuclides $T_{1/2}$ < 5 y	-	-	-	≤10 TBqm^{-3}	NA	NA	-
Remarks *in activated material		Inherent dilution	Recycle or remelt with assured dilution				

ANNEXURE - 7



RESPONSIBLE ORGANISATION
DECOMMISSIONING ORGANISATION
DECOMMISSIONING PROJECT MANAGER
(Head Quarter Cell)
AERB
Support Services
Technical Services
Administration
Finance & Accounts
Contracts & Material Management
Public Relations
Technical Documentation & Records
Waste Manage-ment
Quality Assurance
Health & Safety (Audit functions)
DECOMMISSIONING SUPERINTENDENT
(Site Cell)
Operation Engineers & Supervisors
Technical Planning Progress Co-ordination & Engineering Services
Decommissioning Trade Engineers & Supervisors
Waste Manage-ment
Quality Assurance
Health Physics Unit
Fuel Handling
Utility Operations
Decontamination & Waste Handling
Civil
Mechanical
Electrical
Instrument-ation & Control
Operators
Attendants
Technicians

ANNEXURE- 8

FORMAT OF FINAL DECOMMISSIONING REPORT

To be provided by the Responsible/Operating Organisation to AERB on completion of decommissioning

The final decommissioning report should contain atleast as a minimum the following information:

a) description of the nuclear facility;
b) summary of the decommissioning activities carried out including major deviations and constraints encountered in executing the approved plan;
c) visual record of important activities;
d) audit report highlighting compliance with respect to regulatory stipulations, statutory requirement, quality and acceptance criteria and non-conformance if any;
e) details of any abnormal events that occurred during decommissioning;
f) individual and collective doses during decommissioning;
g) the approved final radiological survey with details of the residual activity;
h) quantity and characterisation of radioactive waste and their destination;
i) types and quantity of materials, equipment released for reuse and the exemption criteria used;
j) details of remaining systems or structures, if any;
k) future use of the decommissioned site and restriction, if any; and
l) lessons learnt during decommissioning.

LIST OF PARTICIPANTS

Committee to prepare Safety Guide for Decommissioning of Nuclear Facilities constituted by AERB

Dates of Meetings: 25 meetings covering 27 days from May 13, 1991 to May 1, 1992

Members participating in the meetings:

Shri T.K.Ghosh (Chairman)	Formerly ED (P), NPC
Shri T.Subbaratnam (acting Chairman)	Formerly Hd, HPD, BARC
Shri V.S.Srinivasan	Chief Engineer, NPC
Shri S.Sankar	Head, ROD, BARC
Shri R.C.Rastogi	Head, WMD (Proj.), BARC
Shri P.M.Wagh	TSS, TAPS
Shri S.A.Sukheswala	HPD, BARC
Shri S.Venkatesan (Member-Secretary)	H & SD, AERB
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ADVISORY COMMITTEE ON NUCLEAR SAFETY

Advisory Committee on Nuclear Safety constituted by AERB

Dates of Meetings: September 23, 1995
October 28, 1995

Members participating in the meetings:

Shri S K.Mehta	(Chairman)	Formerly Director, Reactor Group, BARC
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