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Predisposal Management of Radioactive Waste From Reactors

DRAFT SAFETY GUIDE
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Draft Safety Guide

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PREDISPOSAL MANAGEMENT OF RADIOACTIVE WASTE FROM REACTORS

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1 The production of electricity in nuclear power reactors and in the use of nuclear research reactors generates radioactive waste. Such radioactive waste arising from nuclear power reactors and from research reactors is diverse and variable in nature and encompasses a broad range of radionuclides. Typical waste from reactors include: spent ion exchange resins, filters, activated metals, liquid and gaseous effluents, irradiated experimental components, and spent fuel declared as waste. Because of the variability and diversity in the waste streams from these facilities, particular and constant attention has to be given to all steps of the management of the waste.

1.2 The importance of the safe management of radioactive waste for the protection of human health and the environment has long been recognized. The principles and requirements that govern the safety of the management of radioactive waste are presented in SF-1 [1], GSR Part 1 [2], GSR Part 3 [3] and GSR Part 5 [4].

1.3 GSR Part 5 [4] establishes requirements for the safe management of radioactive waste prior to its disposal. These requirements are derived from the safety principles established in the Safety Fundamentals publication SF-1 [1] and include requirements for the protection of human health and the environment and associated responsibilities. Recommendations on the fulfilment of these requirements are provided in this Safety Guide and several associated Safety Guides.

1.4 The predisposal management of radioactive waste includes all steps or activities in the management of waste, from its initial generation up to disposal. Predisposal management of radioactive waste covers all the steps in the management of radioactive waste from its generation up to disposal, including processing (pretreatment, treatment and conditioning), storage and transport.

1.5 Measures to prevent or minimize the generation of radioactive waste have to be put in place beginning during the design of facilities and the planning of activities that have the potential to generate radioactive waste. This step recognises that the management of the activities that generate radioactive waste is the key to avoiding or minimising quantities produced.

1.6 Predisposal management of radioactive waste covers all the steps in the management of radioactive waste from its generation up to disposal, including processing (pretreatment, treatment and conditioning), storage and transport. Pretreatment may include waste collection, segregation, chemical adjustment and decontamination. Treatment may include volume reduction, radionuclide removal and change of composition. Conditioning involves those operations that transform radioactive waste into a form suitable for subsequent activities such as handling, transport, storage and disposal; this may include immobilization of the waste, placing of the waste into containers and provision of additional packaging. Storage refers to the temporary placement of radioactive waste in a facility where appropriate isolation and monitoring are provided; it is an interim activity with the intent that the waste can be retrieved at a later date for clearance, processing and/or disposal at a later time, or, in the case of effluent, for authorized discharge.

1.7 In cases where no disposal facility is available for the waste, or the waste were to be stored over long periods of time, assumptions will have to be made regarding anticipated acceptance criteria or other anticipated future steps in order to provide guidance for its predisposal management.

1.8 The predisposal management of radioactive waste may take place in a separate, dedicated waste management facility or at specific locations within a larger facility operated for other purposes, e.g. within a nuclear power plant site. In this Safety Guide the term ‘facility’ is used to refer to either of these possibilities and the term

'operator' is used for the operating organization or operator of a designated waste management facility or a waste generator who also performs activities for the predisposal management of waste.

1.9 In addition to its radiological hazard, the waste may present non-radiological hazards owing to its physical or chemical characteristics, as well as conventional health and safety issues, and these should also be taken into account in the predisposal management of radioactive waste.

OBJECTIVE

1.10 The objective of this Safety Guide is to provide regulatory bodies and operators that generate and manage radioactive waste with recommendations on how to meet the requirements for the predisposal management of radioactive waste arising from nuclear power reactors and research reactors.

1.11 This Safety Guide supersedes those parts of the following safety standards that are concerned with the management of radioactive waste from reactors: safety guides WS-G-2.5 on predisposal management of low- and intermediate-level radioactive waste, WS-G-2.6 on predisposal management of high-level radioactive waste, NS-G-2.7 Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants, NS-G-1.13 Radiation Protection Aspects of Design for Nuclear power Plants, and NS-G-4.6 Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors.

1.12 This Safety Guide presents guidance and recommendations on how to meet the requirements established in the following IAEA Safety Requirements publications: Governmental, Legal and Regulatory Framework for Safety [2], International Basic Safety Standards [3], Predisposal Management of Radioactive Waste [4], Safety Assessment for Facilities and Activities [22] and The Management System for Facilities and Activities [8].

SCOPE

1.13 This Safety Guide applies to the predisposal management of radioactive waste of all types arising from nuclear power reactors and research reactors during their commissioning, operation and decommissioning. It covers all the steps in the predisposal management of radioactive waste, from its generation up to disposal.

1.14 This Safety Guide is not specifically intended to cover the storage of spent nuclear fuel as long as it remains a part of the operational activities of a nuclear power plant or research reactor. Storage of spent nuclear fuel in facilities that are collocated with a nuclear power plant or research reactor is addressed in Safety Guide SSG-15, Storage of Spent Nuclear Fuel [5].

1.15 Storage of radioactive waste is not dealt with in detail in this safety guide. This is dealt with in Safety Guide WS-G-6.1, Storage of Radioactive Waste [6]. Transport of radioactive waste must comply with TS-R-1 [7] and is not dealt with in detail in this safety guide.

1.16 Although this publication does not specifically address non-radiological hazards or conventional industrial health and safety issues, these issues also have to be considered by national authorities, both in their own right and in as much as they may affect radiological consequences.

STRUCTURE

to be added later

2. PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

RADIOACTIVE WASTE MANAGEMENT

2.1 The safety objective and the fundamental safety principles established in [1] apply to all facilities and activities in which radioactive waste is generated, processed or stored for the entire lifetime of facilities, including planning, siting, design, manufacture, construction, commissioning, operation, shutdown and decommissioning, and the associated transport of radioactive waste.

2.2 To meet the safety objective, in considering options for the management of radioactive waste, due consideration has to be given to the protection of workers, the public (including future generations) and the environment.

2.3 Safety Requirement GS-R-3, The Management System for Facilities and Activities [8] requires both the regulatory body and the operator to establish a management system that addresses safety, health, environmental, security, quality and economic requirements in an integrated manner. A key component of such a system in an organization is a robust safety culture.

2.4 In controlling the radiological and non-radiological hazards associated with radioactive waste, the following aspects are also required to be considered: conventional health and safety issues, radiation risks that may transcend national borders, and the potential impacts and burdens on future generations arising from long periods of storage of radioactive waste [1].

RADIATION PROTECTION

2.5 The BSS [3] states that the three general principles of radiation protection, which concern justification, optimization of protection and application of dose limits, are expressed in Safety Principles 4, 5, 6 and 10 stated in [1].

2.6 Requirements for radiation protection have to be established at the national level, with due regard to the BSS [3]. In particular, the BSS require radiation protection to be optimized for any persons who are exposed as a result of activities in the predisposal management of radioactive waste, with due regard to dose constraints, and require the exposures of individuals to be kept within specified dose limits.

2.7 National regulations will prescribe dose limits for the exposure of workers and members of the public under normal conditions. Internationally accepted values for these limits are contained in Schedule III of the BSS [3]. In addition to the provision for protection against the exposures that will arise from normal operations referred to in the preceding paragraphs, provision has to be made for protection against potential

exposure from operations outside normal conditions e.g. accidents or other incidents. Requirements for protection against potential exposure are also established in the BSS [3]. They include management and technical requirements to prevent the occurrence of incidents or accidents and provisions for mitigating their consequences if they do occur.

2.8 When choosing options for the predisposal management of radioactive waste, consideration has to be given to both the short term and the long term radiological impacts on workers and members of the public; for example, by balancing present-day exposures resulting from the operation of nuclear facilities and potential exposure that could arise in the future from the disposal of radioactive waste generated by those facilities [1, 9, 10].

2.9 Doses and risks associated with the transport of radioactive waste have to be managed in the same way as those associated with the transport of any radioactive material. Safety in the transport of radioactive waste is ensured by complying with the requirements in [7].

ENVIRONMENTAL CONCERNS

2.10 Requirements for environmental protection that are associated with predisposal management of radioactive waste have to be established by the relevant national regulatory bodies, with all potential environmental impacts that could reasonably be expected being taken into consideration [1, 3].

2.11 To achieve the fundamental safety objective of protecting people and the environment from harmful effects of ionizing radiation, measures have to be taken:

(a) To control the radiation exposure of people and the release of radioactive material to the environment;

(b) To restrict the likelihood of events that might lead to a loss of control over source[s] of radiation; [and]

(c) To mitigate the consequences of such events if they were to occur.

2.12 The operator has a duty in the area of radioactive waste management to take measures to avoid or to optimize the generation, management and disposal of radioactive waste with the aim of minimizing the overall environmental impact, including ensuring that aerial and liquid radioactive releases to the environment are in compliance with authorized limits, and to reduce doses to the public and effects on the environment to levels that are as low as reasonably achievable (optimization of protection).

2.13 Clearance from regulatory control and control of discharges are addressed in IAEA Safety Standards Series Nos. RS-G-1.7, WS-G-2.3 and NS-G-3.2 [10, 11, 12] respectively.

3. ROLES AND RESPONSIBILITIES

LEGAL AND ORGANISATIONAL FRAMEWORK

Requirement 1 (GSR Part 5, Ref. [1]): Legal and regulatory framework

The government shall provide for an appropriate national legal and regulatory framework within which radioactive waste management activities can be planned and safely carried out. This shall include the clear and unequivocal allocation of responsibilities, the securing of financial and other resources, and the provision of independent regulatory functions. Protection shall also be provided beyond national borders as appropriate and necessary for neighbouring States that may be affected.

Requirement 2 (GSR Part 5, Ref. [1]): National policy and strategy on radioactive waste management

To ensure the effective management and control of radioactive waste, the government shall ensure that a national policy and a strategy for radioactive waste management are established. The policy and strategy shall be appropriate for the nature and the amount of the radioactive waste in the State, shall indicate the regulatory control required, and shall consider relevant societal factors. The policy and strategy shall be compatible with the fundamental safety principles and with international instruments, conventions and codes that have been ratified by the State. The national policy and strategy shall form the basis for decision making with respect to the management of radioactive waste.

3.1 The government is responsible for establishing a national policy and corresponding strategies for the management of radioactive waste. The management of radioactive waste should be undertaken within an appropriate national legal and regulatory framework that provides for a clear allocation of responsibilities, and that ensures the effective regulatory control of the facilities and activities concerned [1, 2]. The policy and strategy, as well as the legal framework, should cover all types of radioactive waste and radioactive waste generation, processing and storage facilities in the State, and waste imported or exported from it, with account taken of the interdependences between the various steps of radioactive waste management, the time periods involved and the options available.

3.2 The national legal framework should also establish measures to ensure compliance with other relevant international legal instruments, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [12], and the Convention on Nuclear Safety [13].

3.3 Where nuclear, environmental, industrial safety and occupational health aspects are separately regulated the regulatory framework should recognize that the overall safety is affected by the interdependencies between radiological, industrial, chemical and toxic hazards and ensure that the regulatory framework identifies this and delivers effective control.

3.4 The national legal framework should ensure that the construction of installations adjacent to an existing facility that could prejudice the safety of the facility are monitored and controlled by means of planning requirements or other legal instruments.

3.5 The management of radioactive waste may involve the transfer of radioactive waste from one operating organization to another organization or from one governmental region to another, or may even be processed in another State. Such transfers create interdependencies in responsibilities as well as physical interdependencies in the various steps in the management of radioactive waste. The legal framework should include provisions to ensure a clear allocation of responsibility for safety throughout the entire process, in particular with respect to interface with the storage of radioactive waste and its transfer between operating organizations.

3.6 The government is responsible for establishing a regulatory body independent from the owners of the radioactive waste or the operating organizations managing the radioactive waste, with adequate authority, power, staffing and financial resources to discharge its assigned responsibilities [2].

3.7 Responsibility for safety should be ensured by means of a system of authorization by the regulatory body. For transfers of radioactive waste between States, authorizations from the relevant national regulatory bodies are required [2].

3.8 Interdependences exist between the various steps in the management of radioactive waste. The national and regulatory framework should incorporate clear definitions of the content and responsibilities for the management of the interdependences.

3.9 A mechanism for providing adequate financial resources should be established to cover any future costs, in particular, the costs associated with the storage of radioactive waste, decommissioning of both the management and the storage facilities and also the costs of long term management of radioactive waste, if applicable. The financial mechanism should be established before commissioning and eventual operation, and should be updated as necessary. Consideration should also be given to provision of the necessary financial resources in the event of premature shutdown of the radioactive waste predisposal management facility or early dispatch of the waste to a disposal facility.

3.10 In the event that circumstances change and management techniques change or processing or storage is required beyond the period originally envisaged in the national strategy, a re-evaluation of the national radioactive waste management strategy should be initiated.

3.11 In order to facilitate the establishment of a national policy and strategy, the Government should establish a national inventory of the radioactive waste (current and anticipated, including waste generated during decommissioning and dismantling of facilities) and update it at regular time intervals. This inventory should take into account the Safety Guide on classification of radioactive waste [14].

3.12 Facilities for predisposal management of radioactive waste should have sufficient capacity to process all waste generated and the storage capacity should be sufficient to account for uncertainties in the availability of facilities for treatment, conditioning and disposal.

3.13 The government should consult interested parties on matters relating to the development of national policies and strategies that affect the management of radioactive waste, and should take due account of the concerns of the public.

3.14 The national policy and strategy should address the various waste classes as identified in ref [14] and their long-term management, both from a technical point of view as well as from a human and financial resources point of view.

3.15 As far as possible, the national policy and strategy should also address waste management issues from potential remediation activities resulting from accidents and abnormal events.

RESPONSIBILITIES OF THE REGULATORY BODY

Requirement 3 (GSR Part 5, Ref. [1]): Responsibilities of the regulatory body

The regulatory body shall establish the requirements for the development of radioactive waste management facilities and activities and shall set out procedures for meeting the requirements for the various stages of the licensing process. The regulatory body shall review and assess the safety case [1] and the environmental impact assessment for radioactive waste management facilities and activities, as prepared by the operator both prior to authorization and periodically during operation. The regulatory body shall provide for the issuing, amending, suspension or revoking of licences, subject to any necessary conditions. The regulatory body shall carry out activities to verify that the operator meets these conditions. Enforcement actions shall be taken as necessary by the regulatory body in the event of deviations from, or noncompliance with, requirements and conditions.

3.16 Regulatory responsibilities may include contributing to the technical input for the establishment of policies, safety principles and associated criteria, and for establishing regulations or conditions to serve as the basis for regulatory activities. The regulatory body should also provide guidance to operating organizations on how to meet requirements relating to the safe management of radioactive waste.

3.17 General recommendations for regulatory inspection and enforcement actions relating to radioactive waste management facilities are provided in Safety Guide GS-G-1.3, Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body [15]. The regulatory body should periodically verify that the key aspects of the operation of the radioactive waste management facility meet the requirements of the national legal system and facility license conditions, such as those relating to the keeping of records on inventories and material transfers, requirements for processing, storage, maintenance, inspection, testing and surveillance, operational limits and conditions, emergency preparedness and response. Such verification may be carried out, for example, by routine inspections of the radioactive waste management installations and audits of the operating organization. The regulatory body should verify that the necessary records are prepared and that they are maintained for an appropriate period of time. A suggested list of records is included in Safety Guide GS-G-1.4, Documentation for Use in Regulating Nuclear Facilities [16].

[1] The safety case is a collection of arguments and evidence in support of the safety of a facility or activity. This collection of arguments and evidence may be known by different names (such as safety report, safety dossier, safety file) in different States and may be presented in a single document or a series of documents (see Section 5).

3.18 The regulatory body should set up appropriate means of informing interested parties, such as persons living in the vicinity, the general public, media and others about the safety aspects (including health and environmental aspects) of the radioactive waste management facility and about regulatory processes and should consult these parties, as appropriate, in an open and inclusive manner. The need for confidentiality, e.g. for security reasons, should be respected.

3.19 The regulatory body should consider the licensing strategy to be adopted, for example:

(a) A licence issued for the entire lifetime of the generation, processing and/or storage system and/or installation, which encompasses the entire anticipated operating period, including periodic review of safety assessments; or

(b) A licence issued for a specified time period with the possibility for its renewal after expiration.

3.20 The regulatory review of the decommissioning plans for radioactive waste management installations should follow a graded approach, particularly considering the phases in the lifetime of the radioactive waste management installation. The initial decommissioning plan should be conceptual and should be reviewed by the regulatory body for its overall completeness rather than for specific decommissioning arrangements, but should include specifically how financial and human resources and the availability of the necessary information from the design, construction and operational phases will be ensured for when the decommissioning takes place. The updates of the decommissioning plan as well as the final decommissioning plan should be reviewed by the regulatory body.

3.21 If the regulatory body consists of more than one authority, effective arrangements should be made to ensure that regulatory responsibilities and functions are clearly defined and coordinated, in order to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operating organization. The regulatory functions of authorization, review and assessment, inspection, enforcement and development of regulations and guides should be organized in such a way as to achieve consistency and to enable the necessary feedback and exchange of information.

RESPONSIBILITIES OF THE OPERATING ORGANISATION

Requirement 4 (GSR Part 5, Ref. [1]): Responsibilities of the operator
Operators shall be responsible for the safety of predisposal radioactive waste management facilities or activities. The operator shall carry out safety assessments and shall develop a safety case, and shall ensure that the necessary activities for siting, design, construction, commissioning, operation, shutdown and decommissioning are carried out in compliance with legal and regulatory requirements.

3.22 National policies and strategies and international cooperation in relation to safety of radioactive waste management can evolve over the lifetime of the facility. Policy decisions and technological innovations and advances can lead to fundamental changes in the overall radioactive waste management strategy. However, the

operating organization retains its responsibility for the safety of facility and activities, and a continuous commitment by the organization remains a prerequisite to ensuring safety and the protection of human health and the environment.

3.23 The operating organization is responsible for the safety of all activities associated with the management of radioactive waste (including activities undertaken by contractors) in compliance with the principles contained in [1], and for the identification and implementation of the programmes and procedures necessary to ensure safety and security. The operating organization should maintain a robust safety culture and demonstrate safety and security. In some instances the operating organization may be the owner of the radioactive waste and in other cases the owner may be a separate organization or operating unit.

3.24 In the latter case, the interface between responsibilities of the owner and the operating organisation should be clearly defined, agreed and documented. Information about changes in ownership of the radioactive waste or changes in the relationship between the owner and the operating organisation of the predisposal management facility should be provided to the regulatory body.

3.25 The responsibilities of the operating organization of a radioactive waste management facility typically include:

(a) Application to the regulatory body for permission to site, design, construct, commission, operate, modify or decommission a radioactive waste management facility;

(b) Conducting appropriate safety and environmental assessments in support of the application for a licence and conducting periodic safety reviews;

(c) Operation of the radioactive waste management facility in accordance with the requirements of the safety case, the licence conditions and the applicable regulations;

(d) Development and application of procedures for the receipt, storage and processing of radioactive waste as well as acceptance criteria as approved by the regulatory body;

(e) Ensuring that the waste acceptance criteria at a particular point in the predisposal waste management acknowledges the information required to meet the downstream waste acceptance criteria;

(f) Management of the information required either to support the onward disposition/storage of any radioactive waste or to support the decommissioning of that facility. Especially where the latter may be many decades after normal operations have ceased;

(g) Providing periodic reports as required by the regulatory body (e.g. information on the actual inventory of radioactive waste, any transfers of radioactive waste into and out of the facility, including material cleared from regulatory control, and any events that occur at the facility and which have to be reported to the regulatory body) and communicating with relevant interested parties including those who are remote from the facility or activities;

(h) Conducting appropriate security assessments in order to implement appropriate security measures;

(i) Derivation and implementation of limits, conditions and controls;

(j) Ensuring operations are conducted in compliance with the criteria for the effluent discharges from a radioactive waste management facility as approved or authorized by the regulatory body;

(k) Taking into consideration measures that will control the generation of radioactive waste, in terms of volume and radioactivity content, to the minimum practicable;

(l) Ensuring that radioactive waste that is generated fulfils the acceptance criteria for transport, storage and disposal;

(m) Taking into consideration the decisions that would have to be made in the management of waste if no disposal option is available (this may also include "orphan waste" or legacy waste), or for waste that would need to be stored over long periods of time.

3.26 In the case where waste is generated at the facility, the operating organisation should develop a facility specific waste management programme that:

(a) implements the national waste management policy and strategy;

(b) recognises the connections between the sources of radioactive waste and the eventual discharge, disposal or onward disposition from that facility;

(c) recognises the hierarchy of the following strategic options, which are applicable to predisposal waste management:

(1) Keeping the generation of radioactive waste to the minimum practicable, in terms of both activity and volume, by using suitable technology;

(2) Possible reuse and recycling of materials; and

(3) Treating, retreating and conditioning radioactive waste to ensure safe storage and disposal.

More detailed guidance on facility-specific waste management programmes are provided in Annex 1.

3.27 Prior to authorization of a radioactive waste management facility, the operating organization should provide the regulatory body with a safety case and supporting safety assessment that demonstrates the safety of the proposed activities and demonstrates that the proposed activities will be in compliance with the safety requirements and criteria set out in national laws and regulations. The operating organization should use the safety assessment to establish specific operational limits, conditions and operational controls. The operating organization may wish to set an operational target level below these specified limits to assist in avoiding any breach of approved limits and conditions.

3.28 At an early stage in the lifetime of a radioactive waste management facility, the operating organization should prepare preliminary plans for its eventual decommissioning. For new facilities, features that will facilitate decommissioning

should be taken into consideration at the design stage; such features should be included in the decommissioning plan together with information on arrangements for how the availability of the necessary human and financial resources and information will be assured, for presentation in the safety case.

3.29 For existing facilities without a decommissioning plan, such a plan should be prepared as soon as possible. Requirements on decommissioning are established in Safety Requirement WS-R-5, Decommissioning of Facilities Using Radioactive Material [17] and recommendations are provided in Safety Guide WS-G-2.4, Decommissioning of Nuclear Fuel Cycle Facilities [18].

3.30 The awareness by individuals of safety matters and the commitment of individuals to safety are essential. Radioactive waste management facilities may require special considerations to achieve high safety, security, health and environmental standards. The operating organization should take measures to review the safety culture and adopt and implement the necessary principles and processes to improve the safety culture.

3.31 The operating organization should establish the requirements for training and qualification of its staff and contractors, including for initial and periodic refresher training. The operating organization should ensure that all staff members concerned understand the safety case, the nature of the radioactive waste, its potential hazards and the relevant operating and safety procedures to the extent required by their responsibilities. Supervisory staff should be competent to perform their activities and should therefore be selected, trained, qualified and authorized for that purpose. A radiation protection officer should be appointed to oversee the application of radiation protection requirements.

3.32 The operating organization should carry out pre-operational tests and commissioning tests to demonstrate compliance of the radioactive waste management facility and its activities with the requirements of the safety case and supporting safety assessment and with the safety requirements established by the regulatory body.

3.33 The operating organization should ensure that discharges of radioactive and other potentially hazardous materials to the environment are in accordance with the conditions of licence or authorisation.

3.34 Discharges, disposals and transfers to other facilities should be documented. Such documents should be retained until the facility has been fully decommissioned or by agreement with the regulator.

3.35 The operating organization should prepare plans and implement programmes for personnel monitoring, area monitoring, environmental monitoring, and for emergency preparedness and response.

3.36 The operating organization should establish a process for authorization that also includes evaluation of modifications to the radioactive waste management facility and activities, operating conditions, or the radioactive waste to be processed or stored, using a graded approach that is commensurate with the safety significance of the modifications. The process of evaluating the potential consequences of such modifications should also consider potential consequences for the safety of other facilities and also for the subsequent storage, reprocessing or disposal of radioactive waste.

3.37 The operating organization is required to put in place appropriate mechanisms for ensuring that sufficient financial resources are available to undertake all necessary tasks throughout the lifetime of the facility, including its decommissioning [2].

3.38 The operating organization should develop and maintain a records system on the generation, processing and storage of radioactive waste, which should include the radioactive inventory, location and characteristics of the radioactive waste, and information on ownership and origin (Safety Guide GS-G-3.3, The Management System for the processing, handling and storage of radioactive waste) [19]. Such records should be preserved and updated, to enable the implementation of the facility specific radioactive waste management plan. Such a records system should be managed as required by the national authority.

3.39 The operating organization should draw up emergency plans on the basis of the potential radiological impacts of accidents [19] and should be prepared to respond to accidents at all times as indicated in the emergency plans.

4. INTEGRATED APPROACH TO SAFETY

SAFETY AND SECURITY

Requirement 5: Requirements in respect of security measures

Measures shall be implemented to ensure an integrated approach to safety and security in the predisposal management of radioactive waste.

4.1 Safety and security measures have in common the aim of protecting human life and health and the environment. These must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

4.2 In the management of radioactive waste, a balance must be created between the requirements for safety and security on one hand, and operational needs and costs on the other hand. Such balance depends on the nature of the material (fissile or non-fissile), on the nature of the source (sealed or non-sealed), radionuclide content and activity, and also on the individual step in the predisposal management. As a facility moves through its lifecycle these balances change but are most significantly present from the generation of the radioactive waste until its eventual transport to a disposal facility or where it is discharged via an authorized route.

4.3 In addition, physical protection systems for deterrence and detection of the intrusion of unauthorized persons and against sabotage from within and outside the facility will should be designed and installed during the construction and operation of the radioactive waste management facility.

4.4 The implications of such systems and arrangements on the safety of the facility should be assessed and it should be ensured that no safety function would be

compromised nor would the overall level of safety at the facility be significantly reduced on account of such systems and arrangements.

4.5 When material is required to be accessed for waste management or safeguard purposes this should take account of requirements for security, radiation protection, and waste management.

4.6 Both monitoring and access should take account of the hazards and risks associated with the radioactive waste and associated operations such that operators and the public are not exposed to undue harm.

INTERDEPENDENCES

Requirement 6 (GSR Part 5, Ref. [1]): Interdependences

Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account.

4.7 Interdependences exist among all steps in the management of radioactive waste, from the generation of the waste to its disposal. In selecting strategies and activities for the predisposal management, planning should be carried out for all the various steps so that a balanced approach to safety is taken in the overall management programme and conflicts between the safety requirements and operational requirements are avoided. There are various alternatives for each step in the management of radioactive waste. To ensure safety, all the different steps should be evaluated, both as isolated steps in the process and also as part of an integrated system in which the steps are complementary and mutually dependent. For example, treatment and conditioning options are influenced by the established or anticipated acceptance requirements for disposal.

4.8 The interdependences among the steps in the predisposal management of radioactive waste should be considered for achieving continuity in operations. The following aspects in particular should be considered:

(a) The identification of interfaces and the definition of the responsibilities of the various organizations involved at these interfaces;

(b) The establishment of acceptance criteria, where necessary, and the confirmation of conformance with the acceptance criteria by means of verification tests or the examination of records.

4.9 For many programmes for the management of radioactive waste, decisions about predisposal management have to be made before the waste acceptance requirements for disposal are finalized. Decisions on the predisposal management should be made and implemented so as ultimately to ensure compliance with the waste acceptance requirements for disposal. In particular, in the design and preparation of waste packages for the disposal of radioactive waste, consideration should be given to the suitability of the packages for transport and storage, including retrieval, and to their suitability for emplacement in a disposal facility on the basis of the anticipated waste

acceptance requirements. The suitability of waste packages should be kept under periodic review as the technology for waste disposal is developed.

4.10 Given that disposal is the final step in the management of radioactive waste that cannot be otherwise cleared, discharged or reused, the selected or anticipated disposal option also needs to be taken into account when any other upstream radioactive waste management activity is being considered. However, in many Member States disposal facilities are not yet available in general or only for specific types of waste. Independent of this, all radioactive waste arisings must be managed, requiring decisions on waste forms to be produced which, in this situation, must be made before all radioactive waste management activities are finally established.

4.11 Where there is no disposal facility yet available or defined, then an interim position should be defined such that either options are not foreclosed or all reasonably practicable steps have been taken to prepare waste for the anticipated disposal option. The interdependencies between the waste generation facility, predisposal waste management facility and the (existing or anticipated) disposal facility should also be defined.

4.12 Site and facility waste management programmes should identify all relevant interdependencies and include arrangements to ensure that they are appropriately considered from the point of generation to the point of disposal. For example, the disposal waste acceptance criteria should be known and appropriately considered when the waste is generated. Recognising that at the point of generation the controls and information associated with the waste will be aligned with the next stage of pre-disposal waste management and that of the disposal facility. Thus the waste acceptance criteria for each step of predisposal waste management should be aligned with the waste acceptance criteria of the next step of pre-disposal waste management ultimately to disposal.

MANAGEMENT SYSTEM

Requirement 7 (GSR Part 5, Ref. [1]): Management systems

Management systems shall be applied for all steps and elements of the predisposal management of radioactive waste.

4.13 The requirements on management systems for all stages in the lifecycle of a predisposal management facility are set in Ref. [7]. General guidance on the management systems for facilities and activities is given in Ref. [20], while specific guidance on the management systems for predisposal management facilities is provided in Ref. [21].

4.14 An integrated management system (safety, health, environmental, security, quality and economic elements) is required to be established, implemented, assessed and continually improved by the operating organization and it should be applied to all steps of the predisposal management of radioactive waste [8]. It should be aligned with the goals of the operating organization and should contribute to their achievement. The management system should make provision for siting, design, commissioning, operation, maintenance and decommissioning of the predisposal

radioactive waste management facility. The management system should be designed to ensure that the safety of the radioactive waste management facilities are maintained, and that the quality of the records and of subsidiary information on radioactive waste inventories is preserved, with account taken of the duration of the management and storage periods and the consecutive management steps, for example, clearance, release, discharge, reprocessing or disposal. The management system should also include provision to ensure that the fulfilment of its goals can be demonstrated.

4.15 Managing radioactive waste involves a variety of activities that may extend over a very long period of time. These characteristics present a series of challenges to the development and implementation of effective management systems for a waste management programme, and give rise to the need for an integrated management system to deal with all matters that might affect the management of radioactive waste, including the financial provisions to carry it out.

4.16 For achieving and maintaining an integrated management system the following long term aspects should be considered:

(a) Preservation of technology and knowledge and transfer of such knowledge to people joining the operating organization in the future;

(b) Retention or transfer of ownership of radioactive waste and management facilities;

(c) Succession planning for the technical and managerial human resources;

(d) Continuation of arrangements for interacting with interested parties.

(e) Provision of adequate resources (the adequacy of resources for maintenance of facilities and equipment may need to be periodically reviewed over operational periods that may extend over decades);

RESOURCE MANAGEMENT

4.17 Radioactive waste management activities will require financial and human resources and the necessary infrastructure at the site where the radioactive waste is located. Senior management should be responsible for making arrangements to provide adequate resources for radioactive waste management activities, to satisfy the demands imposed by the safety, health, environmental, security, quality and economic aspects of the full range of activities involved in the management of radioactive waste and the potentially long duration of such activities.

4.18 Where the management of radioactive waste is anticipated to be multi-decade then the operator should interface with the government to ensure that there are national policies and plans to maintain the underpinned knowledge associated with management of radioactive waste via national education and training required to deliver safety and environmental protection

4.19 The generator of the radioactive waste should establish an appropriate funding mechanism. Arrangements for funding of future radioactive waste management activities should be specified, and responsibilities, mechanisms and schedules for

providing the funds should be established in due time. Management systems for radioactive waste management activities should include provision to deal with several funding challenges:

(a) For various reasons (e.g. bankruptcy, cessation of business), it may not be feasible to obtain the necessary funds from the radioactive waste generator, especially if funds were not set aside at the time the benefits were received from the activity, or if ownership of the radioactive waste has been transferred to other parties.

(b) If funds are to come from public sources, this will compete with other demands for public funding and it may be difficult to gain access to adequate funds on a timely basis.

(c) It may be difficult to make realistic estimates of costs for radioactive waste management activities that are still in the planning stage and for which no experience has been accumulated.

(d) It may be difficult to estimate anticipated costs for activities that will only begin in the long term, because they will depend strongly on assumptions made about future inflation rates, interest rates and technological developments.

(e) It may be difficult to determine appropriate risk and contingency factors to be built into estimates of future costs, owing to the uncertainties associated with future changes in societal demands, political imperatives, public opinion and the nature of unplanned events that may require resources for dealing with them.

(f) If several organizations are involved in radioactive waste management activities, the necessary financial arrangements may be complex and may vary over the lifetime of the facility. It may be problematic to establish an adequate degree of confidence in all the arrangements so that the necessary continuity of funding throughout the entire series of activities is ensured.

PROCESS IMPLEMENTATION

4.20 The management system should be periodically reviewed through the use of self-assessments, independent assessments, and management system reviews. It should accommodate the feedback of experience from implementation and from internal and external lessons learned. It should be flexible enough to accommodate changes in policy; in strategic aims; in safety, health, environmental, security, quality and economic considerations; and in regulatory requirements and other statutes.

4.21 Management systems should also be reassessed whenever the relationship between the owner of the radioactive waste and the operating organization of the facility changes (e.g. public organizations are privatized, new organizations are created, existing organizations are combined or restructured, responsibilities are transferred between organizations, operating organizations undergo internal reorganization of the management structure, or resources are reallocated).

4.22 In the design of facilities for long term radioactive waste management, consideration should be given to the incorporation of measures that will facilitate operation, maintenance of equipment and eventual decommissioning of the facility. For long

term radioactive waste management activities, future infrastructural requirements should be specified and plans should be made to ensure that these will be met. In such planning, consideration should be given to the continuing need for support services, spare parts for equipment that may eventually no longer be manufactured and equipment upgrades to meet new regulations and operational improvements, and to the evolution and inevitable obsolescence of software. Consideration should also be given to the need to develop monitoring programmes and inspection techniques for use during extended periods of storage.

4.23 Consideration should be given to the possible need to relocate radioactive waste if problems arise after it has been placed in storage (e.g. threats to the integrity of containers or problems associated with criticality or decay heat). The availability of any specialized equipment that may be necessary over a long time period while radioactive waste is in storage or that may be necessary in the future should be assessed.

4.24 Records concerning the radioactive waste and its storage that need to be retained for an extended period should be stored in a manner that minimizes the likelihood and consequences of loss, damage or deterioration due to unpredictable events such as fire, flooding or other natural or human initiated occurrences. Storage arrangements for records should meet the requirements prescribed by the national authorities or the regulatory body and the status of the records should be periodically assessed. If records are inadvertently destroyed, the status of surviving records should be examined and the importance of their retention and their necessary retention periods should be re-evaluated.

5. SAFETY CASE AND SAFETY ASSESSMENT

Requirement 13 (GSR Part 5, Ref. [1]): Preparation of the safety case and supporting safety assessment

The operator shall prepare a safety case and a supporting safety assessment. In the case of a step by step development, or in the event of the modification of the facility or activity, the safety case and its supporting safety assessment shall be reviewed and updated as necessary.

Requirement 14 (GSR Part 5, Ref. [1]): Scope of the safety case and supporting safety assessment

The safety case for a predisposal radioactive waste management facility shall include a description of how all the safety aspects of the site, the design, operation, shutdown and decommissioning of the facility, and the managerial controls satisfy the regulatory requirements. The safety case and its supporting safety assessment shall demonstrate the level of protection provided and shall provide assurance to the regulatory body that safety requirements will be met.

Requirement 15 (GSR Part 5, Ref. [1]): Documentation of the safety case and supporting safety assessment

The safety case and its supporting safety assessment shall be documented at a level of detail and to a quality sufficient to demonstrate safety, to support the decision at each stage and to allow for the independent review and approval of the safety case and safety assessment. The documentation shall be clearly written and shall include arguments justifying the approaches taken in the safety case on the basis of information that is traceable.

Requirement 16 (GSR Part 5, Ref. [1]): Periodic safety reviews

The operator shall carry out periodic safety reviews and shall implement any safety upgrades required by the regulatory body following this review. The results of the periodic safety review shall be reflected in the updated version of the safety case for the facility.

Requirement 22 (GSR Part 5, Ref. [1]): Existing facilities

The safety at existing facilities shall be reviewed to verify compliance with requirements. Safety related upgrades shall be made by the operator in line with national policies and as required by the regulatory body.

5.1 Facilities that generate radioactive waste should only be authorized to operate if the operating organization provides the regulatory body with a safety case and supporting safety assessment that demonstrates that the proposed facilities or activities will be operated safely and in compliance with the safety requirements and criteria set out in national laws and regulations. The operating organization should use the safety assessment to establish specific operational limits, conditions and administrative controls. The operating organization may wish to set an operational target level below the limits and controls to assist in avoiding any breach of those that may be approved.

5.2 Requirements for the safety assessment for facilities and activities are set in GSR Part 4 [22]. Requirements for the safety case and safety assessment for all facilities and activities are set in GSR Part 5 [4]. Guidance on the safety case and safety assessment for predisposal management of radioactive waste is provided in the Safety Guide for the Safety Case and Safety Assessment for Predisposal Management of Radioactive Waste (DS284) [23].

5.3 The safety assessment and the periodic safety reviews of nuclear power plants and research reactors normally include the safety assessment and review of the waste treatment systems within the reactor facility [24, 25, 26]. This typically includes:

- Description of the design and operation of radioactive waste management systems (waste generation and control, waste treatment and conditioning, storage)
- Limits for releases to the environment
- Organisational responsibilities
- Management of safety and radiation protection, including operational limits and controls

5.4 The safety case and supporting safety assessment should provide the primary input to the licensing documentation required to demonstrate compliance with regulatory requirements with consideration of the integration of the whole of pre-disposal waste management. An important outcome of the safety case and safety assessment is the facilitation of communication between interested parties on issues relating to the facility or activity.

5.5 The safety case and supporting safety assessment should demonstrate that consideration has been given to all steps in the management of the waste under consideration, from its generation to its disposal, and to their overall compatibility. Thus, short term, medium term and long term aspects of waste management should be considered, as well as the possible need for future handling and treatment of the waste and the risks and doses that may be associated with these activities.

5.6 The safety case and supporting safety assessment should address the compatibility of the waste packages and unpackaged waste with the existing or anticipated disposal option; however, in the event that a disposal option does not exist, assumptions should be made about the likely disposal options and these should be set down clearly.

5.7 The safety case should include identification of uncertainties in the performance of the waste management activities, analysis of the significance of the uncertainties, and identification of approaches for the management of significant uncertainties. Such uncertainties should be a focus of an examination of the interdependencies between the boundaries of interlinking safety cases.

5.8 Long term storage of radioactive waste at the reactor site e.g. after the reactor has been decommissioned or shut down, requires special consideration in the safety case and safety assessment [6, 23]. This includes assessment of passive safety features, package and packaging requirements, institutional controls, retention of records, emergency preparedness and response plans, decommissioning plan, human intrusion and monitoring and inspection. The safety case should also consider degradation of engineered features and availability of maintenance and emergency response systems, changes to the stored waste and uncertainties in parameters and models used.

6. STEPS IN THE PREDISPOSAL MANAGEMEMENT OF RADIOACTIVE WASTE

GENERAL

6.1 The steps involved in the predisposal management of radioactive waste are:

- waste generation and control
- pre-treatment
- treatment
- conditioning

- storage
- transport

6.2 At various steps it should be verified that the waste complies with acceptance criteria. Therefore the waste has to be characterised and classified throughout the steps of predisposal management.

6.3 The ultimate goal of predisposal management of radioactive waste is to make the waste suitable for disposal (or for storage if no disposal facility is available). This implies that the final waste form has to comply with the waste acceptance criteria for disposal.

6.4 If no disposal facility is available for the waste, specific assumptions should be made on the requirements for the acceptance of the waste for disposal in order to provide guidance for its predisposal management. These assumptions should be justified and agreed upon by the waste generator, the operator of the predisposal management facility and the regulator.

6.5 Radioactive waste is to be handled and transported between and within the various steps in predisposal management. Requirements and guidance on transport of radioactive waste can be found in TS-R-1 [7] and TS-G-1.1 [27].

WASTE MINIMIZATION

Requirement 8: Radioactive waste generation and control

All radioactive waste shall be identified and controlled. Radioactive waste arisings shall be kept to the minimum practicable.

6.6 The generation of radioactive waste cannot be prevented entirely but must be kept to the minimum practicable (‘waste minimization’) as an essential objective of radioactive waste management. Waste minimization relates to both volume and activity, and should be applied to waste generated by an initial undertaking and the secondary waste resulting from the predisposal management of radioactive waste. The chemical characteristics of the waste should also be controlled at the source to facilitate the subsequent processing of the waste.

6.7 Waste minimisation is achieved by an understanding of the operations involved in the management of the radioactive material that generates radioactive waste. The control measures are generally applied in the following order: reduce waste generation, reuse items as originally intended, recycle materials and, finally, consider disposal as waste.

6.8 Useful strategies for waste minimization include:

(a) Reducing the volume of radioactive waste to be managed, by adequate segregation and by keeping non-radioactive material out of controlled areas to prevent contamination;

(b) The proper planning of activities and the use of adequate equipment for handling waste so as to control the generation of secondary waste;

(c) The segregation of material to prevent contamination and subsequent inability to reuse non-contaminated material.

(d) The decontamination of material, together with the control of secondary waste arising from decontamination;

(e) The recycling and reuse of materials and structures, systems and components.

6.9 Consideration should be given to the design of the facility and to operational features for waste minimization, including the following aspects:

(a) The careful selection of materials, processes and structures, systems and components for the facility;

(b) The selection of design options that favour waste minimization when the facility is eventually decommissioned;

(c) The use of effective and reliable techniques and equipment;

(d) The containment and packaging of radioactive material to maintain its integrity;

(e) The decontamination of zones and equipment and the prevention of the spread of contamination.

6.10 The principle of waste minimization should also be a factor for consideration in the selection of approaches to storage and processing. Examples of processing steps for which this principle should be considered include the selection of conditioning processes and the testing programme invoked to verify treatment and conditioning processes. For a conditioning process in which components become contaminated, equipment of proven longevity should be used.

6.11 Management options such as authorized discharge, authorized disposal, recycling, reuse and the removal of regulatory control from materials, in compliance with the conditions and criteria established by the regulatory body, should be used as far as practicable.

6.12 The management of radioactive waste, in particular segregation and pre-treatment activities, should be carried out so as to minimize the amount of radioactive waste to be further treated, stored and disposed of. Decontamination and/or a sufficiently long period of storage to allow for radioactive decay should be used where appropriate to enable regulatory control to be removed from the waste.

Radioactive Waste from Power Reactors

Gaseous radioactive waste

6.13 Although the sources of gaseous radioactive waste differ according to the type of reactor, possible sources include: leakage from the coolant, the moderator systems or the reactor itself; degasification systems for the coolant; condenser vacuum air ejectors or pumps; the exhaust from turbine gland seal systems; and activated or contaminated ventilated air. In all cases, spent fuel in storage or in handling operations is a potential source of gaseous radioactive waste.

6.14 The generation of gaseous radioactive waste should be kept to the minimum practicable by means of measures such as:

(a) operating the reactor so as to avoid fuel failures and optimizing the time period for which leaking fuel remains in the reactor core;

(b) reducing leakage from the pressure boundary for the primary coolant and moderator;

(c) keeping levels of coolant and moderator impurities (e.g., fission products, radiolysis products) as low as practicable;

(d) filtering gaseous effluents, as appropriate;

(e) careful planning of maintenance activities to reduce the possibility of leakage of gaseous waste.

Liquid radioactive waste

6.15 The primary coolant in water cooled reactors and water from the fuel storage pools are major sources of liquid radioactive waste since some of their radioactive content may be transported to the liquid radioactive waste stream via process streams or leakages. Although the composition of the liquid radioactive waste may vary appreciably according to reactor type, contributions to the stream may derive from reactor coolant let-down, evaporator concentrates, equipment drains, floor drains, laundry waste, contaminated oil and waste arising from the decontamination and maintenance of facilities and equipment.

6.16 The generation of liquid radioactive waste should be kept to the minimum practicable by means of measures such as:

(a) the proper selection of reactor materials, for example, by avoiding materials containing cobalt;

(b) operating the reactor so as to avoid fuel failures and optimizing the time period for which leaking fuel remains in the reactor core;

(c) reducing leakage from the primary coolant system and other connected systems;

(d) chemical adjustment of the cooling system and avoidance of deposits;

(e) planning and performing maintenance work with due care and with particular emphasis on precautions to avoid the spread of contamination;

(f) taking precautions to avoid the contamination of equipment and rooms in order to reduce the need for decontamination;

(g) optimizing decontamination procedures;

(h) reducing the production of secondary waste by the appropriate selection of waste processing methods.

Solid radioactive waste

6.17 Solid radioactive waste results from the operation and maintenance of the nuclear power plant and its associated processing systems for gaseous and liquid radioactive waste. The nature of such waste varies considerably from plant to plant, as do the associated levels of activity. Solid radioactive waste may consist of: spent ion exchange resins (both bead and powder); cartridge filters and pre-coat filter cake; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; debris from fuel assemblies or in-reactor components; and contaminated rags, clothing, paper and plastic.

6.18 The production of solid radioactive waste should be kept to the minimum practicable by minimizing the amounts of gaseous and liquid wastes generated, thereby reducing the amounts of processed waste, and by means of measures such as:

(a) careful planning and performance of maintenance work;

(b) careful control of the packaging and handling of radioactive materials;

(c) avoiding the generation of secondary radioactive waste, for example, by placing restrictions on taking packaging and other material into the controlled area;

(d) efficient operation of processing systems for gaseous and liquid radioactive waste;

(e) effective procedures for the control of contamination and the implementation of effective decontamination methods;

(f) good segregation practices, including clearance of materials, at points of waste generation;

(g) the reuse and recycling of materials wherever possible;

(h) selection of materials that do not easily become activated.

Radioactive Waste from Research Reactors

Gaseous radioactive waste

6.19 The typical sources of gaseous radioactive waste generated during the operation of research reactors include:

(a) Gaseous radioactive elements or compounds from the pools, coolant systems, irradiation facilities and experimental facilities;

(b) Airborne radioactive material produced in ancillary facilities, including fume cupboards and decontamination areas.

6.20 The generation of radioactive gaseous waste should be kept to the minimum practicable by means of measures such as:

(a) The areas with potential for the generation of gaseous waste should have provisions for the renewal of air and its purification through filters;

(b) The ventilation system of the controlled areas outside the containment or means of confinement should include high efficiency particulate air (HEPA) filters and charcoal beds or demisters prior to discharge to the stack;

(c) An atmosphere of an inert gas such as nitrogen should be used for the transfer and cooling of irradiation targets;

(d) Levels of coolant impurities should be kept as low as practicable;

(e) Maintenance activities should be carefully planned to reduce the possibility of leakage of gaseous waste.

Liquid radioactive waste

6.21 The typical sources of liquid radioactive waste generated during the operation of research reactors include:

(a) Cooling water blowdown;

(b) Primary system drains (in the case of light water reactors);

(c) Liquid waste from the demineralized water plant;

(d) The drain of the ventilation water system;

(e) Demineralized waste water recovered from the drainage of large equipment in maintenance operations;

(f) Washbasin and shower liquids;

(g) Floor drain liquids;

(h) Liquids from laboratories (these can be radioactive or non-radioactive).

6.22 The generation of liquid radioactive waste should be kept to the minimum practicable by means of measures such as:

(a) The proper selection of reactor materials, for example by avoiding materials containing cobalt;

(b) Reducing leakage from the various systems;

(c) Chemical adjustment of the coolant and avoidance of deposits;

(d) Planning and performing maintenance work with due care and with particular emphasis on precautions to avoid the spread of contamination;

(e) Taking precautions to avoid contamination of equipment and building surfaces to reduce the need for decontamination;

(f) Optimizing decontamination procedures;

(g) Reducing the production of secondary waste by the appropriate selection of waste processing methods.

Solid radioactive waste

6.23 The typical sources of solid radioactive waste generated during the operation of research reactors include:

(a) Irradiated target cans;

(b) Used irradiation rigs and reactor components (e.g. thermocouples);

(c) Neutron beam guide tubes;

(d) Used control rods;

(e) Waste arising from the pool service area;

(f) Ventilation system waste (charcoal filters, HEPA filters);

(g) Spent ion exchange resins;

(h) Cleaning materials and used personal protective items;

(i) Laboratory waste (gloves, tissue paper, disposable glassware, etc.);

(j) Contaminated items arising from maintenance and other works.

6.24 The generation of solid radioactive waste should be kept to the minimum practicable level by means of measures such as:

(a) Careful planning and performance of maintenance work;

(b) Careful control of the packaging and handling of radioactive material;

(c) Avoiding the generation of secondary radioactive waste by, for example, placing restrictions on packaging and other unnecessary material being taken into the controlled area;

(d) Efficient operation of processing systems for gaseous and liquid radioactive waste;

(e) Effective procedures for the control of contamination and the use of effective methods of decontamination;

(f) Adopting good segregation practices, including clearance of materials, at the point of waste generation;

(g) Selection of materials that do not easily become activated (e.g. use of pure plastic for the target carriers used in the pneumatic rabbit system);

(h) reuse and recycling of materials wherever possible (e.g. use of titanium cans).

REMOVAL OF REGULATORY CONTROL FROM WASTE MATERIAL AND DISCHARGES TO THE ENVIRONMENT

6.25 Requirement 8 of the BSS [3] stipulates that “The regulatory body shall approve which sources, including materials and objects, within notified or authorized practices may be cleared from further regulatory control, using as the basis for such approval the criteria for clearance specified in Schedule I or any clearance levels specified by

the regulatory body on the basis of such criteria." The waste generator or operator should have a formal mechanism in place to demonstrate compliance with regulatory requirements in respect of clearing materials from regulatory control. Additionally, there should be compliance with other requirements on release regarding any other hazardous aspects of the waste.

6.26 The waste generator or operator should have a formal mechanism in place to demonstrate compliance with regulatory requirements for the clearance of materials from regulatory control. Additionally, there should be compliance with other requirements on release regarding any other hazardous aspects of the waste.

6.27 One of the principle approaches to predisposal management of radioactive waste "dilute and disperse" refers to the discharging of effluent to the environment in such a way that environmental conditions and processes ensure that the concentrations of the radionuclides are reduced to such levels in the environment that the radiological impacts of the released material are acceptable. The limitations and controls for such releases should be set by the regulatory body (WS-G-2.3, Regulatory Control of Radioactive Discharges to the Environment) [29].

CHARACTERIZATION OF WASTE AND ACCEPTANCE CRITERIA

Requirement 9: Characterization and classification of radioactive waste

At various steps in the predisposal management of radioactive waste, the radioactive waste shall be characterized and classified in accordance with requirements established or approved by the regulatory body.

6.28 Radioactive waste is required to be characterized at the various stages in its predisposal management to obtain information on its properties for use in controlling the quality of the products, verifying the process and thus facilitating the subsequent steps for safely processing and finally disposing of the radioactive waste.

6.29 For the purposes of determining arrangements for the handling, treatment and storage of radioactive waste, consideration should be given to:

(a) Its origin;

(b) Criticality [29];

(c) Its radiological properties (e.g. half-life, activity and concentration of nuclides, dose rates);

(d) Other physical properties (e.g. size and mass, compactibility, solubility);

(e) Chemical properties (e.g. corrosion resistance, combustibility, gas generation properties);

(f) Biological properties (e.g. biological hazards);

(g) Intended methods of processing, storage and disposal

6.30 The characterization process should include the measurement of physical and chemical parameters, the identification of radionuclides and the measurement of

activity content. Such measurements are necessary for monitoring the history of the radioactive waste or waste packages through the stages of conditioning, storage and disposal and for maintaining records for the future.

6.31 The data requirements for characterization and methods for collecting data will differ depending on the type and form of the radioactive waste. When waste streams are processed, characterization may be performed by sampling and analysing the chemical, physical and radiological properties of the waste. The quality of waste packages may be investigated by non-destructive and, infrequently, also by destructive methods. However, it may be possible to apply indirect methods of characterization based on process control and process knowledge instead of or in addition to sampling and the inspection of waste packages in order to avoid undue occupational exposure. The methods of characterization in the processing of the waste should be approved by the regulatory body in the authorization process. The characterisation of spent nuclear fuel declared as waste should provide the information outlined in Appendix 1.

6.32 An important objective of the predisposal management of radioactive waste is to produce waste packages that can be handled, transported, stored and disposed of safely. In particular, radioactive waste should be conditioned to meet the acceptance requirements for its disposal. In order to provide reasonable assurance that the conditioned waste can be accepted for disposal, although there may not yet be any specific requirements, options for the future management of radioactive waste and the associated waste acceptance requirements should be anticipated as far as possible. The waste acceptance requirements may be met by providing an overpack that is tailored to the specific conditions of the disposal facility and to the characteristics of the radioactive waste and the engineered components of the disposal facility.

6.33 To ensure the acceptance of waste packages for disposal, a programme should be established to develop a process for conditioning that is approved by the regulatory body. The features adopted for waste characterization and process control should provide confidence that the properties of waste packages will be ensured.

6.34 The categorization and classification of radioactive waste assists in the development of management strategies and in the operational management of the waste. Segregation of waste with different properties will also be helpful at any stage between the arising of the raw waste and its conditioning, storage, transport and disposal. To make the appropriate segregation of waste, it will be necessary to know its properties and, hence, it will be necessary to characterize the waste at various stages of its processing. Documented procedures should be followed for the characterization of radioactive waste and its segregation, and for assigning the waste to a particular class.

6.35 Details of the purpose, methods and approaches to the classification of radioactive waste are provided in GSG-1 [14]. Annex III of [14] also provides information on origin and types of radioactive waste, including waste from nuclear power production. The classification scheme is based on the long-term management (disposal) of the radioactive waste.

6.36 It should be borne in mind that certain types of radioactive waste contain alpha emitting radionuclides, which could arise from failed fuel. Inflammable, pyrophoric,

corrosive or other hazardous materials should also be given special attention. Care should be taken to avoid mixing waste of these types.

6.37 Gaseous radioactive waste should be classified for treatment purposes into waste arising directly from the primary coolant systems of the reactor and waste arising from the ventilation of plant areas.

6.38 Liquid radioactive waste should be classified for processing purposes according to its activity concentration and its content of chemical substances. For instance, radioactive waste containing boric acid or organic matter may need special treatment. Non-aqueous radioactive waste such as oil should be segregated for separate treatment.

6.39 Solid radioactive waste should be classified according to its radionuclide content (type and half-life) and activity concentration; for instance, sludge, cartridge filters, contaminated equipment and components, ventilation filters and miscellaneous items (such as paper, plastic, towels) may be segregated in accordance with the type of treatment and conditioning process, such as compaction, incineration or immobilization.

6.40 The segregation of radioactive waste into appropriate categories should be carried out as near to the point of generation as practicable. The waste should be segregated in accordance with written procedures.

PROCESSING OF RADIOACTIVE WASTE

Requirement 10: Processing of radioactive waste

Radioactive material for which no further use is foreseen and with characteristics that make it unsuitable for authorized discharge, authorized use or clearance from regulatory control shall be processed as radioactive waste. The processing of radioactive waste shall be based on appropriate consideration of the characteristics of the waste and of the demands imposed by the different steps in its management (pretreatment, treatment, conditioning, transport, storage and disposal). Waste packages shall be designed and produced so that the radioactive material is appropriately contained during both normal operation and in accident conditions that could occur in the handling, storage, transport and disposal of waste.

INTRODUCTION

6.41 The predisposal management of radioactive waste may include one or more processing steps (e.g. pre-treatment, treatment and conditioning). The handling, storage and transport of the waste will be necessary within, between and after such steps.

6.42 The objective of predisposal management is to produce packages of conditioned radioactive waste suitable for safe handling, transport, storage and disposal. If no disposal facility is available, assumptions should be made on the requirements for the acceptance of the waste for disposal in order to provide guidance for its predisposal management.

6.43 Radioactive waste should be processed as early as practicable in order to convert it into a passively safe state and to prevent its dispersal during storage and disposal.

PRE-TREATMENT

6.44 The processing of radioactive waste will include pre-treatment operations such as waste collection, segregation, chemical adjustment and decontamination. Pre-treatment may result in a reduction in the amount of waste needing further processing and disposal. Actions can be performed to adjust the characteristics of the waste, to make it more amenable to further processing, and to reduce or eliminate certain hazards posed by the waste owing to its radiological, physical and chemical properties.

6.45 The first operation in the pre-treatment of radioactive waste is to collect waste materials, segregating them as necessary on the basis of their radiological, physical and chemical properties. Radioactive waste containing predominantly short lived radionuclides should not be mixed with long lived waste. In the segregation of waste it should also be taken into account whether regulatory control can be removed from the waste or whether it can be recycled or released, either directly or after allowing for a decay period.

6.46 To facilitate further treatment and enhance safety, solid waste should be segregated according to the facility specific waste management programme and the available facilities. Considerations for segregation include:

(a) Combustible or non-combustible, if incineration is a viable option;

(b) Compressible or non-compressible, if compaction is a viable option;

(c) Metallic or non-metallic, if melting is a viable option;

(d) Fixed or non-fixed surface contamination, if decontamination is a viable option.

6.47 Special care should be taken in segregating materials and objects that are fissile, pyrophoric, explosive, chemically reactive or otherwise hazardous, or that contain free liquids or pressurized gases.

6.48 A number of decontamination processes remove surface contamination using a combination of mechanical, chemical and electrochemical methods. Care should be taken to limit the amount of secondary waste generated and to ensure that the characteristics of the secondary waste are compatible with subsequent steps in the waste management process.

6.49 To the extent possible, liquid waste should be characterized on the basis of its physical, radiological and chemical properties to facilitate collection and segregation. With proper characterization it may be possible to release the waste within authorized limits, provided that the non-radiological characteristics of the waste are appropriate.

6.50 Mixing waste streams should be limited to those streams that are radiologically and chemically compatible. If the mixing of chemically different waste streams is considered, an evaluation should be made of the chemical reactions that could occur in order to avoid uncontrolled or unexpected reactions. Organic liquid waste needs

different treatment owing to its chemical nature and should be segregated and kept separate from aqueous waste streams. Organic liquid waste may also be flammable and its collection and storage should incorporate provisions for adequate ventilation and fire protection.

TREATMENT

6.51 The treatment of radioactive waste may include:

(a) The reduction in volume of the waste (by incineration of combustible waste, compaction of solid waste and segmentation or disassembly of bulky waste components or equipment);

(b) The removal of radionuclides (by evaporation or ion exchange for liquid waste streams and filtration of gaseous waste streams); and

(c) Change of form or composition (by chemical processes such as precipitation, flocculation and acid digestion as well as chemical and thermal oxidation).

SOLID WASTE

6.52 Solid radioactive waste may be heterogeneous. Special consideration should be given to representative sampling before processing so as to confirm compatibility with the intended process, and appropriate arrangements should be made for this as far as practicable. Arrangements should also be made for systematic control of the final products to verify compliance with established requirements and recommendations.

6.53 A great number of processes are available for producing acceptable waste packages. Such processes should be selected on the basis of the characteristics of the waste concerned. If possible, processes with high volume reduction factors should be applied with the use of proven techniques such as compaction or incineration.

6.54 Incineration of combustible solid waste normally achieves the highest volume reduction as well as yielding a stable waste form. After combustion, radionuclides from the waste will be distributed between the ash, the products from cleaning the exhaust gases and the stack discharges. The distribution will depend on the design and operating parameters of the incinerator and the nature of the radionuclides in the waste. Incineration is also an advantageous technique for treating radioactive organic liquids because the products of complete combustion are ash, carbon dioxide and water. Other constituents in the waste may yield acid gases and corrosive combustion products, and the effects of corrosion of the incinerator’s components and of acid releases to the atmosphere should therefore be considered. Off-gas scrubbing to prevent the discharge of radioactive and non-radioactive hazardous materials may be necessary and should be considered. Attention should be paid to radionuclides accumulating in residues of the gas cleaning system and those remaining in the ash, and to their further conditioning. It should be noted that incineration will result in the increase of the activity concentration which might result in a change of the waste class.

6.55 For incinerators processing significant amounts of radioactive waste, the operator should monitor the radionuclides in the stack discharge by appropriate measures to ensure that the concentrations and amounts discharged are within the limits specified by the regulatory body and are consistent with the parameters modelled in the safety assessment. The products of incineration can include acids, polychlorinated biphenyls and various other materials presenting non-radiological hazards, which should be taken into account.

6.56 Compaction is a suitable method for reducing the volume of certain types of waste. The characteristics of the material to be compacted and the desired volume reduction should be well defined and controlled. Consequences of compaction that should be given consideration in selecting or designing and operating a compactor include the following:

(a) The possible release of volatile radionuclides and other airborne radioactive contaminants;

(b) The possible release of contaminated liquid during compaction;

(c) The chemical reactivity of the material during and after compaction;

(d) The potential fire and explosion hazards due to pyrophoric or explosive materials or pressurized components.

6.57 Segmentation or disassembly and other size reduction techniques may be used before conditioning waste that is bulky or oversize in relation to the intended processing (e.g. worn out components or structures). Processes to achieve this typically use cutters with high temperature flames, various sawing methods, hydraulic shearing, abrasive cutting and plasma arc cutting. Means of preventing the spread of particulate contamination should be considered in the choice of method and in the operation of the equipment.

6.58 For non-combustible and non-compressible solid waste, for which delay and decay or decontamination is not a viable option, direct conditioning without prior treatment should be considered. Melting metal scrap, with resultant homogenization of the radioactive material and its accumulation in the slag, may be considered as a means of achieving authorized reuse or removal of regulatory control.

6.59 If the operating organization uses a mobile conditioning unit rather than a permanently installed plant, care should be taken to prevent unnecessary contamination in the connection and disconnection operations with mobile units.

LIQUID WASTE

6.60 In the operation of processing systems for liquid radioactive waste, consideration should be given to the amounts of liquids to be treated, the radionuclides present, the activity, the concentrations of particulates, the chemical compositions, the toxicity and the possible presence of corrosive substances.

6.61 Input streams should be characterized, in particular for new facilities, either before liquid waste streams reach the processing facility or early in the processing activities. By this means, different types of waste can be segregated appropriately and, if

various options are available, the most effective methods of processing can be adopted.

6.62 Methods for the treatment of aqueous waste include evaporation, chemical precipitation, ion exchange, filtration, centrifugation, ultrafiltration, incineration and reverse osmosis. In each case, process limitations due to corrosion, scaling, foaming and the risk of fire or explosion in the presence of organic material should be carefully considered, especially with regard to the safety implications of operations and maintenance. If the waste contains fissile material, the potential for criticality should be evaluated and eliminated to the extent practicable by means of design features and administrative features [29].

6.63 For the effective processing of liquid waste, the following practices should normally be adopted:

(a) When more than one means of processing liquid radioactive waste is available to the operator, the choice should be made on the basis of careful consideration of all factors, including occupational exposure, public exposure and the generation of secondary waste.

(b) Waste of higher activity should not be mixed with lower activity waste if it may be easier to provide containment and shielding for a small volume of higher activity waste.

(c) The chemical compatibility of different waste streams, and of the radioactive waste and the equipment, should be taken into consideration.

(d) If liquids are recycled after treatment and conditioning, attention should be paid to the possibility of chemical cross-contamination so as to avoid unnecessary processing.

(e) The possible incompatibility of radioactive waste with components of the treatment and conditioning plant (for example, due to the potential for corrosion or scaling of evaporators) should be taken into consideration and the chemical composition of the waste should be kept under strict control in its processing.

(f) If radioactive waste outside the normal range of composition is to be processed, consideration should be given to flushing the equipment before it is returned to normal duties.

(g) Strict in-plant control over all parameters relevant to waste processing should be maintained.

6.64 Spent ion exchange resins are usually flushed out as slurry and subsequently managed as liquid waste, although some operators retain the resins as a dry solid. When resins are slurried, care should be taken to prevent blockages of the flow as these may cause radiation hot spots and necessitate special maintenance. Special care should also be taken with their prolonged storage while awaiting conditioning, because of the potential for radiolysis or chemical reactions generating combustible gases or causing physical degradation or exothermic reactions.

6.65 Liquids for discharge may be produced as a consequence of the treatment of waste. All discharged liquids should be readily dispersible in water. If the liquid contains suspended materials, it may need to be filtered prior to discharge. Waste that is

immiscible with water should be completely excluded from discharge. Acidic or alkaline liquids should be neutralized prior to discharge. If the waste also contains toxic or other chemicals that could adversely affect the environment or the treatment of sewage, the waste should be treated prior to discharge in accordance with the regulations in respect of health and safety and environmental protection.

6.66 For routine discharges of liquids to the environment, the main types of control options are to provide either storage facilities, so that short lived radionuclides can decay before release, or treatment facilities that remove radionuclides from the effluent stream for disposal by other means. Within these two broad categories there may be a number of different options available. The limitations and controls for such releases should be set by the regulatory body [28].

GASEOUS WASTE

6.67 In the operation of treatment systems for gaseous radioactive waste, consideration should be given to: the amount of gas to be treated; the activity; the radionuclides contained in the gas; the concentrations of particulates; the chemical composition; the humidity; the toxicity; and the possible presence of corrosive or explosive substances.

6.68 Noble gases with short half-lives should be retained in hold-up tanks or other delay systems that allow the radionuclides to decay to an acceptable activity or activity concentration before release.

6.69 Radioactive particulates and aerosols in gaseous effluents may be removed by filtration using high efficiency particulate air (HEPA) filters. Iodine and noble gases can be removed by filters or sorption beds charged with activated charcoal. The use of scrubbers for the removal of gaseous chemicals, particulates and aerosols from off-gases should be considered. Where required by the regulatory body, or if the reliability of the system is fundamental to the achievement of safety, redundant systems such as two filters in sequence should be used in case one fails. Additional components of the off-gas system that should be considered for detecting problems include those that ensure proper operation of the filters, such as pre-filters or roughing filters, and temperature and humidity control systems, as well as monitoring equipment such as gauges that show pressure differentials.

6.70 If necessary, personnel should wear appropriate protective clothing and breathing apparatus when testing, maintaining or replacing filters or adsorbing beds so as to minimize the inhalation of particulates accumulated on the filters or the structures.

6.71 If combustible material is present or explosive mixtures may be formed, suitable prevention and control measures to reduce potential hazards should be established and taken.

6.72 Used filters and sorption beds are considered to be solid waste. The physical and chemical properties of the selected filter masses should therefore be compatible with the treatment and conditioning processes for the solid waste streams in which they will be treated. Care should be taken to ensure that the trapped radioactive substances are not dispersed in an uncontrolled manner during the replacement of the filters or the subsequent treatment of radioactive substances.

6.73 Measures should be established for sampling and monitoring releases in compliance with regulatory criteria.

CONDITIONING

6.74 Conditioning of radioactive waste consists of those operations that produce a waste package suitable for safe handling, transport, storage and disposal. Conditioning may include the immobilization of liquid waste or dispersible waste, the enclosure of the waste in a container and the provision of an overpack (as necessary).

6.75 Waste packages produced by conditioning should satisfy the respective acceptance criteria. Therefore, the regulatory body and organizations operating or planning to operate transport services and storage and disposal facilities should be consulted in deciding which types of pre-treatment, treatment and conditioning will be necessary.

6.76 Liquid waste is often converted into a solid form by solidifying it in a suitable (in accordance with the waste acceptance criteria) matrix such as cement, bitumen, glass or polymer. Solidification may also be achieved without a matrix material, for example by drying. The product is then enclosed in a container.

6.77 To the extent practicable the solidification process for liquid waste should produce a waste form with the following characteristics and properties:

(a) Compatibility (physical and chemical) of the waste, any matrix materials and the container;

(b) Homogeneity;

(c) Low voidage;

(d) Low permeability and leachability;

(e) Chemical, thermal, structural, mechanical and radiation stability for the required period of time;

(f) Resistance to chemical substances and organisms.

6.78 Solid waste should be considered on a case by case basis. The characteristics of the waste form as listed above apply for many types of solid waste. Some of the characteristics (in particular homogeneity and low voidage) do not apply for certain types of solid waste.

6.79 It should be taken into account that certain metals, such as aluminium, magnesium and zirconium, could react with, for example, the alkaline water of a cement slurry or water diffused from a concrete matrix, to produce hydrogen. Chelating agents, organic liquids or oil and salt content in liquid waste may also be of concern in the conditioning process.

6.80 The waste and its container should be compatible. Depending on the waste characteristics and the method of handling, transport and storage, the container may also need to provide shielding for direct radiation. In selecting materials for the container and its outer surface finish, consideration should be given to the ease of decontamination. If a waste package is not initially designed to meet the relevant

acceptance criteria for transport, storage or disposal, an additional container or an overpack will be necessary to meet the acceptance criteria. Care should be taken to consider the compatibility of the waste package and the overpack with respect to the waste acceptance criteria and transport requirements.

6.81 The waste package should provide integrity during the predisposal storage period and should be capable of allowing for:

(a) Retrieval at the end of the storage period;

(b) Enclosure in an overpack, if necessary;

(c) Transport to and handling at a disposal facility;

(d) Performance as required in the disposal environment.

STORAGE OF RADIOACTIVE WASTE

Requirement 11: Storage of radioactive waste

Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved in a condition suitable for its subsequent management. Due account shall be taken of the expected period of storage, and, to the extent possible, passive safety features shall be applied. For long term storage in particular, measures shall be taken to prevent the degradation of the waste containment.

6.82 Guidance for the storage of radioactive waste is dealt with extensively in [6].

RADIOACTIVE WASTE ACCEPTANCE CRITERIA

Requirement 12: Radioactive waste acceptance criteria

Waste packages and unpacked waste that are accepted for processing, storage and/or disposal shall conform to criteria that are consistent with the safety case.

6.83 Criteria are to be developed for the acceptance of radioactive waste in the facilities for predisposal management. Account should be taken of all relevant operational limits and conditions of the predisposal management facility (consistent with the safety case) and also of the future disposal facility. In fact, an important objective of the predisposal management is to produce waste packages that can be handled, transported, stored and disposed of safely. In particular, waste should be conditioned to meet the acceptance requirements for its disposal. In order to provide reasonable assurance that the conditioned waste can be accepted for disposal, although there may not yet be any specific requirements, options for the future management of radioactive waste and the associated waste acceptance requirements should be anticipated as far as possible. The waste acceptance requirements may be met by providing an overpack that is tailored to the specific conditions for disposal and to the characteristics of the waste and the engineered components of the disposal facility. Annex 2 provides a listing of the typical properties and characteristics that should be considered for waste packages in the predisposal management of radioactive waste.

6.84 To ensure the acceptance of waste packages for disposal, a programme should be established, as an element of the management system, to develop a process for conditioning that is approved by the regulatory body.

6.85 The operator of the predisposal management facility should ensure that the radioactive waste accepted in his facility (and installations) complies with the set criteria. Procedures for acceptance should be included in the management system.

6.86 Adequate techniques need to be in place to identify the characteristics of the material to demonstrate that it meets the waste acceptance criteria.

7. LIFECYCLE SAFETY CONSIDERATIONS

INTRODUCTION

7.1 The general phases in the lifecycle of nuclear facilities including pre-disposal management facilities are the following:

(a) Siting

(b) Design

(c) Construction

(d) Commissioning

(e) Operation

(f) Decommissioning

SITING AND DESIGN

Requirement 17: Location and design of facilities

Predisposal radioactive waste management facilities shall be located and designed so as to ensure safety for the expected operating lifetime under both normal and possible accident conditions, and for their decommissioning.

7.2 Criteria and methods that could be used in the siting of a facility for nuclear installations are dealt with in [30], [31] and [32].

7.3 Facilities for the predisposal management of radioactive waste on any particular site should be located in the same area, to the extent practicable, to reduce the need for the transport of waste between locations for processing and for storage.

7.4 A facility for the predisposal management of radioactive waste should be designed for a specified design lifetime. The design should facilitate the maintenance, including replacement of components, as necessary in order to limit the radiation exposure of workers and to prevent accidents.

7.5 Facilities for the predisposal management of radioactive waste should have sufficient capacity to process all such waste generated and the storage capacity should be sufficient to account for uncertainties in the availability of facilities for treatment, conditioning and disposal. The possible need to process waste that may arise non-routinely from incidents and accidents, and for major maintenance necessitating the dismantling of structures, systems or components at nuclear facilities, should be taken into account in the design of a facility.

7.6 In the design of a facility for the predisposal management of radioactive waste, due consideration should be given to the need for:

(a) Reduction of the quantity and concentration of the radioactive waste generated, and transported within the facility, including decommissioning waste;

(b) Protection against radiation (by shielding and containment, provisions for the decontamination of personnel and equipment);

(c) The control of access to areas for waste processing and storage and the control of movement between radiation zones and contamination zones;

(d) The retrieval of stored waste (including waste generated during operation);

(e) Waste characterization and inventory control;

(f) The inspection of the waste and its containment;

(g) Dealing with waste and waste packages that do not meet specifications;

(h) The control of liquid and gaseous effluents;

(i) Ventilation and the filtration of airborne releases of radioactive material;

(j) Managing waste giving rise to non-radiological hazards;

(k) Maintenance work and eventual decommissioning;

(l) Fire protection and the prevention of explosions;

(m) The prevention of criticality;

(n) Controls for safeguards and security of nuclear materials with due regard for safety.

7.7 Measures considered in the design for the management of gaseous effluents should include the following:

(a) Provision for radioactive gases to be channelled through proper ducting as appropriate and brought to a common release point;

(b) Provisions for the proper selection of process gases and decay devices to minimize releases of radioactive material;

(c) Provision of means, such as stacks for the release of gaseous low level radioactive waste, and of methods for sampling and monitoring those releases.

7.8 Measures considered in the design for the management of liquid radioactive waste should include the following:

(a) Collection of radioactive liquid effluents to a common point such as a holding tank;

(b) The potential for re-concentration downstream of some released radionuclides in relation to the collection of liquid radioactive waste with low levels of activity and the methods of monitoring such releases;

(c) The management and control of liquid radioactive waste with higher levels of activity, such as waste that might arise from planned major shutdowns of research reactors of some types;

(d) Provisions for decay devices to minimize releases of radioactive material;

(e) Provisions for sampling from and monitoring retention tanks prior to the release of liquid content, preferably at the point of release;

(f) Provisions for treating liquid radioactive waste either for reuse (e.g. treatment using resins) or because the activity levels are too high for their release to the environment.

7.9 Measures considered in the design for the management of solid radioactive waste should include the following:

(a) Provisions for segregating waste by type (amount, form, volume, isotopic composition and activity concentration);

(b) The packaging, handling and storage of solid low level radioactive waste, such as contaminated cleaning equipment, clothing, paper and tools;

(c) The packaging, handling and storage of solid intermediate level radioactive waste, such as waste arising from ion exchange resins, ventilation filters and charcoal beds;

(d) The packaging, handling and storage of solid high level radioactive waste such as replaceable core internals;

(e) Areas and tools for handling and loading waste;

(f) Equipment and tools for radiation protection;

(g) Provisions as necessary for storing resins and dehydrating liquid waste;

(h) Provisions for filtration in liquid waste collection lines to prevent the release of solids;

(i) Provisions for ensuring that any solid materials that may be discharged in liquid effluents are within authorized limits.

7.10 Structural materials, fabrication and construction techniques, and testing procedures should be based on codes and standards that are acceptable to the regulatory body. Consideration should be given to the potential effects that the waste, any associated material and the environmental conditions may have on the capabilities of any safety related features of the facility to perform their intended functions. Processes and properties that should be considered include, for example, the high temperature corrosion of material and the effects of irradiation in high radiation fields.

7.11 Facilities for the predisposal management of radioactive waste should be designed to prevent material interactions that may compromise the containment of the waste or safety at the facility.

7.12 The predisposal management of radioactive waste may also entail the management of nonradioactive hazardous material. Material should be selected and other measures should be taken so as to ensure that its management is in compliance with the applicable regulations relating to hazardous material and to take account of potential interactions between radioactive and non-radioactive constituents.

7.13 Depending on the characteristics of the waste concerned, protection may be provided solely by a container or by a container supplemented by the safety systems of the facility, such as those for heat removal (either passive or active).

7.14 For the conditioning of waste, all relevant characteristics of the waste form need to be considered and provided for in the design of the waste package. The waste package should provide adequate containment, shielding and heat removal properties.

7.15 The design and operation of a facility for the predisposal management of radioactive waste should be carried out in such a way as to ensure subcriticality in both operational states and under accident conditions by means of safe geometrical configurations, limitations on concentrations and inventories of fissile material or the use of neutron poisons. An appropriate limiting neutron multiplication factor, with suitable safety factors for mass, concentration and other characteristics taken into account, should be selected in the design for the purpose of ensuring criticality safety, depending upon the conditions mentioned above. Additional organizational and administrative arrangements that may be necessary in the operation of such a facility to ensure subcritical conditions should be considered [29].

7.16 The design of a facility for the predisposal management of heat generating waste should incorporate systems (e.g. a system for monitoring and controlling the temperature) that are capable of maintaining the temperature of the waste within acceptable limits in all stages of predisposal management, both in normal operations and under accident conditions. Such temperature limits should be based on the properties of the waste and waste packages, with account taken of the material properties of the container, the containment structures and the waste form in all steps of management, including storage. To the maximum extent practicable, the cooling systems for storage facilities for conditioned high-level waste should be passive and should need minimal maintenance. If forced circulation of coolant is used, the system should be highly reliable and redundant (robust). Examples of features that enhance the reliability of cooling systems are the capability of dealing with the settling of solids and with build-up on surfaces that affects the efficiency of heat removal. The storage facility itself should be designed to be capable of experiencing temporary loss of cooling events without damage to the stored waste. In addition, means of mitigation or recovery should be put in place to deal with such contingencies.

7.17 Where high radiation fields and high activities are involved, radiation doses should be kept as low as reasonably achievable by the use of features such as remote handling techniques for operations and maintenance and by establishing limits on the activities and dose rates for the items to be removed from highly contaminated or radioactive areas to less contaminated or radioactive areas. When manual maintenance operations

are foreseen, adequate protection should be provided, for example, by the decontamination of equipment and the use of temporary or permanent shielding.

CONSTRUCTION AND COMMISSIONING

Requirement 18: Construction and commissioning of the facilities

Predisposal radioactive waste management facilities shall be constructed in accordance with the design as described in the safety case and approved by the regulatory body. Commissioning of the facility shall be carried out to verify that the equipment, structures, systems and components, and the facility as a whole perform as planned.

7.18 Commissioning involves a logical progression of tasks intended to demonstrate the correct functioning of features specifically incorporated into the design of the facility. In addition, in commissioning, operating procedures are verified and the readiness of staff to operate the facility is demonstrated. The operating procedures should cover both operational states and accident conditions.

7.19 The basis for commissioning should be established at an early stage in the design process as an intrinsic part of the project to facilitate its effective implementation. Commissioning plans should be reviewed and, where appropriate, made subject to approval by the regulatory body. The responsibilities of the various groups typically involved in commissioning should be clearly established. Arrangements should be established to cover:

(a) Specification of tests to be carried out (test objectives, safety criteria to be met);

(b) Provision and approval of documentation;

(c) Responsibilities;

(d) Safety during testing;

(e) Control of test work;

(f) Recording and review of test results;

(g) Interaction with the regulatory body;

(h) Management of equipment providing temporary commissioning aids and its removal before commencement of operation (and after completion of tests).

7.20 Arrangements for testing should include the following:

(a) Regulatory requirements;

(b) Progression through the stages of commissioning;

(c) Reporting of results and approval for operation;

(d) Retention of records.

7.21 For modular storage systems, most of the commissioning will have been completed on loading of the first storage module. Some of the commissioning processes may

become a part of regular operation as new modules are brought into service. However, a change in module design may require some of the commissioning steps to be repeated for the new design.

7.22 Commissioning will usually be completed in several stages:

(a) Completion of construction;

(b) Equipment testing;

(c) Demonstration of performance;

(d) Non-active commissioning;

(e) Active commissioning.

7.23 In the stage of completion of construction, the facility should undergo detailed physical inspection to confirm compliance with the detailed design. Factors such as physical dimensions and levels of background radiation should be determined. A systematic check against design drawings and project documentation should be carried out to establish the as-built status of the facility. In addition to providing information to facilitate operation of the facility, this check can also be important when considering possible future modifications and ultimate decommissioning of the facility.

7.24 In the equipment testing stage, the equipment and systems of the facility should be energized and the various controls tested. Activities such as load testing of lifting equipment should also be carried out and the safe control of equipment should be demonstrated during these tests. If necessary, it should also be demonstrated that the physical interaction between items of equipment is limited.

7.25 In the performance demonstration stage, after individual items of equipment have been tested, a range of tests should be performed to demonstrate the safe interaction of all equipment and the overall operational capability and capacity of the facility. At this stage, the safety and effectiveness of all instructions and procedures should be demonstrated. This should include demonstration of satisfactory training of operating personnel for both normal operation and anticipated operational occurrences. The ability of personnel to conduct maintenance work safely and effectively should also be demonstrated.

7.26 The non-active commissioning stage should provide a formal demonstration that the facility personnel, equipment and procedures function in the manner intended, especially those identified in the safety case, as important to the safety of facility operation. All safety features that can be tested without the presence of radioactive waste should be checked before they are put into operation.

7.27 Once non-active commissioning has been satisfactorily accomplished, the active commissioning stage is commenced with the introduction of radioactive material into the facility. All tests and any resulting amendments should be completed before the introduction of radioactive material. The introduction of radioactive material effectively marks the start of the operation of the facility and, hence, from this stage, the relevant safety requirements for facility operation apply. Active commissioning should include a range of tests to demonstrate that the design criteria for radiation protection have been met.

7.28 Upon completion of commissioning, a final commissioning report should be prepared. This should detail all testing carried out and should provide evidence of its successful completion. The report should demonstrate to the regulatory body that its requirements have been met and may provide the basis for the subsequent licensing of the storage facility for full operation. Additionally, any changes to the facility or to procedures implemented during commissioning should be documented in an appropriate way in the final commissioning report.

FACILITY OPERATION

Requirement 19: Facility operation

Predisposal radioactive waste management facilities shall be operated in accordance with national regulations and with the conditions imposed by the regulatory body. Operations shall be based on documented procedures. Due consideration shall be given to the maintenance of the facility to ensure its safe performance. Emergency preparedness and response plans, if developed by the operator, are subject to the approval of the regulatory body.

OPERATING PROCEDURES

7.29 Facilities for predisposal management of radioactive waste should be operated in accordance with written procedures prepared by the operating organization. These documents and their updates should be prepared in cooperation with the organizations responsible for the design of the facility. However, the operating organization is responsible for ensuring that the procedures are prepared, reviewed, approved and issued appropriately. These procedures should, as a minimum, be such as to ensure compliance with the operational limits and conditions for the facility and, more generally, with the safety assessment.

7.30 Instructions and procedures should be prepared for normal operations of the facility, anticipated operational occurrences and design basis accident conditions. Instructions and procedures should be prepared so that the designated responsible person can readily perform each action in the proper sequence. Responsibilities for approval of any deviations from operating procedures that may be necessary for operational reasons should be clearly specified.

7.31 Adequate arrangements should be made for the review and approval of operating procedures, the systematic evaluation of operating experience, including that of other (similar) facilities, and the taking of corrective actions in a timely and appropriate manner to prevent and counteract developments adverse to safety. Provision should be made for controlling the distribution of operating procedures, in order to guarantee that operating personnel have access to only the latest approved edition.

7.32 The operating organization should ensure that operating procedures relating to the maintaining of subcriticality are subjected to rigorous review and compared with the safety requirements of the design. This may include confirmatory analysis and review by the regulatory body. Some of the factors that should be considered in this review include:

(a) The nature of the waste to be stored;

(b) Geometries necessary to ensure subcriticality;

(c) Waste form and waste packages;

(d) Handling operations;

(e) The potential for abnormal operation;

(f) Dependence of subcriticality on neutron absorbers.

7.33 Operating procedures should be developed for containment systems in the facility (e.g. ventilation and filtration systems) to provide for their monitoring. Such monitoring should be such that the operating organization will be able to determine when corrective actions are necessary to maintain safe operational conditions.

7.34 There are other safety considerations that should be taken into account in the development of operating procedures and contingency and emergency arrangements [33]. It should be noted that many events would be addressed either as anticipated operational occurrences or as design basis accidents. However, some of these events could also lead to severe accidents, which are beyond the design basis. Whilst the probability of such beyond design basis accidents occurring is extremely low, in the preparation of operating procedures and contingency plans the operating organization should consider events such as the following:

(a) Catastrophic crane failure;

(b) Loss of safety related facility process systems such as supplies of electricity, process water, compressed air and ventilation;

(c) Explosions due to the build-up of gases generated by radiolysis;

(d) Fires leading to the damage of items important to safety (to reduce the risk of fire, the amount of combustible material or waste should be controlled, as should be the amount of other flammable materials);

(e) Natural events, such as extreme weather conditions and earthquakes;

(f) External human induced events (airplane crash, sabotage, etc.);

(g) Failure of the physical protection system.

7.35 Operating experience and events at the facility and reported by similar facilities should be collected, screened and analysed in a systematic way. Conclusions should be drawn and implemented by means of an appropriate feedback procedure. Any new standards, regulations or regulatory guidance should also be reviewed to check for their applicability for safety at the facility.

OPERATIONAL LIMITS AND CONDITIONS

7.36 Operational limits and conditions should be developed on the basis of the following:

(a) Design specifications and operating parameters and the results of commissioning tests;

(b) The sensitivity of items important to safety and the consequences of events following the failure of items, the occurrence of specific events or variations in operating parameters;

(c) The accuracy and calibration of instrumentation equipment for measuring safety related operating parameters;

(d) Consideration of the technical specifications for each item important to safety and the need to ensure that such items continue to function in the event of any specified fault occurring or recurring;

(e) The need for items important to safety to be available to ensure safety in operational states including maintenance;

(f) Specification of the equipment that should be available to enable a full and proper response to postulated initiating events or design basis accidents;

(g) The minimum staffing levels needed to operate the facility safely.

7.37 Operational limits and conditions form an important part of the basis on which operation is authorized and as such should be incorporated into the technical and administrative arrangements that are binding on the operating organization and operating personnel. Operational limits and conditions, which result from the need to meet legal and regulatory requirements, should be developed by the operating organization and subject to approval by the regulatory body as part of the licence conditions. The operating organization may wish to set an administrative margin below the operational limits as an operational target to remain within the approved limits and conditions.

7.38 The aim of operational limits and conditions is to manage and control the hazards associated with the facility. Operational limits and conditions should be directed towards:

(a) Preventing situations that might lead to the unplanned exposure of workers and the public to radiation;

(b) Mitigating the consequences of any such events, if they were to occur.

7.39 Personnel directly responsible for operation of the facility should be thoroughly familiar with the facility's operating procedures and the operational limits and conditions to ensure compliance with their provisions. Systems and procedures should be developed in accordance with the approved management system and operating personnel should be able to demonstrate compliance with the operational limits and conditions.

7.40 Operational limits and conditions should be kept under review and may also have to be revised as necessary in accordance with the national regulatory framework for the following reasons:

(a) In the light of operating experience;

(b) Following modifications made to the facility and the type of radioactive waste;

(c) As part of the process of periodically reviewing the safety case (including as part of periodic safety review) for the facility;

(d) If there are changes in legal or regulatory conditions.

7.41 As a result of operating experience, technological progress or changes, corresponding changes to operational conditions may be necessary. Such changes should be justified through safety assessment and should be subject to approval by the regulatory body.

MAINTENANCE

7.42 Before the operation of the facility is commenced, the operating organization should prepare a programme for maintenance, inspection and testing of items important to safety, i.e. structures, systems and components. Safe access should be provided to all structures, systems, areas and components requiring periodic maintenance, inspection and testing. Such access should be adequate for the safe operation of all necessary tools and equipment and for the installation of spares.

7.43 In the programme, starting dates for all inspections should be specified and these should be re-evaluated in the light of results from commissioning tests. The safety case for the facility will form a basis for preparation of the programme in terms of the items, i.e. structures, systems and components, that should be included and the periodicity of planned activities for each item.

7.44 The programme of periodic maintenance, inspection and testing should be subjected to periodic review, with account taken of operating experience. All such activities should be covered in an integrated manner by the management system, with account taken of manufacturers' recommendations.

7.45 The standard and frequency of activities for periodic maintenance, inspection and tests should be such that the level of reliability and effectiveness is ensured and remains in accordance with the design assumptions and intent so that a consistently high level of safety is maintained throughout the lifetime of the facility. Equally, the reliability and effectiveness of any component should not be significantly affected by the frequency of testing, which may result in premature wear and failure or induced maintenance errors, or which could cause unavailability to an unacceptable degree if the component is inoperative during maintenance and testing.

7.46 In general, the maintenance schedule should take into account:

(a) analysis of maintenance requirements on the basis of previous experience or other applicable data (such as manufacturers' recommendations);

(b) work planning in relation to the availability of skilled personnel, tools and materials (including spare items);

(c) the monitoring programme for radiation protection and industrial safety;

(d) the potential for a loss of containment;

(e) impact to operating facilities/maintenance.

7.47 If maintenance, inspection or testing of the facility can be carried out only while certain equipment is in a shutdown state, the maintenance schedule should be drawn up accordingly.

7.48 The maintenance, inspection and testing programme should take into account the structures, systems and components that are affected by the operational limits and conditions, as well as any regulatory requirements.

7.49 Suitably qualified and experienced operating personnel should be deployed in the approval and implementation of the maintenance, inspection and testing programme and in the approval of associated working procedures and acceptance criteria.

7.50 The maintenance and modification of any item of equipment, process or document of the facility should be subject to specified procedures. These procedures should be subject to authorization before they are implemented. The procedures should describe the categorization of the modification in accordance with its safety significance. Depending upon the safety categorization, each modification will be subject to varying levels of review and approval by management of the facility and the regulatory body.

7.51 The maintenance or modification of any item of equipment should be appropriately recorded and documented together with its commissioning test results. The documents should be revised immediately after completion of the maintenance or modification.

RADIATION PROTECTION PROGRAMME

7.52 An operational radiation protection programme should be put in place that ensures that areas of the facility are classified according to the radiation levels and that access control is in place in accordance with the level of classification. It should cover the monitoring of radiation levels in the facility and should include provision to ensure that personnel working in the facility are provided with appropriate dosimetry. A programme of work planning should also be put in place to ensure that radiation exposure is kept as low as reasonably achievable.

TRANSPORT

7.53 The on-site transport of radioactive waste may not need to meet all the requirements for off-site transport [7], because transport is at all times under the control of the operator, who is responsible for the safety of on-site operations.

EMERGENCY PLANNING AND RESPONSE

7.54 The potential radiological impacts of incidents and accidents should be assessed by the operating organization and reviewed by the regulatory body. The operating organization should develop an emergency plan to ensure that there is an effective capability to respond to incidents and accidents. Considerations should include the

development of scenarios of anticipated sequences of events and the establishment of emergency procedures and an emergency plan to deal with each of the scenarios, including checklists and lists of persons and organizations to be alerted.

7.55 Emergency response procedures should be documented, made available to the personnel concerned and kept up to date. The need for exercises should be assessed. If there is such a need, exercises should be held periodically to test the emergency response plan and the degree of preparedness of the personnel. Inspections should be performed regularly to ascertain whether equipment and other resources necessary in the event of an emergency are available and in working order.

SHUTDOWN AND DECOMMISSIONING

Requirement 20: Shutdown and decommissioning of facilities

The operator shall develop, in the design stage, an initial plan for the shutdown and decommissioning of predisposal radioactive waste management facilities and shall periodically update it throughout the operational period. The decommissioning of the facility shall be carried out on the basis of the final decommissioning plan, as approved by the regulatory body. In addition, assurance shall be provided that sufficient funds will be available to carry out shutdown and decommissioning.

7.56 Consideration should be given to the eventual decommissioning of the facility, as regards both facilitating the decommissioning activities and keeping the generation of radioactive waste to the minimum practicable, in the design of a facility for the predisposal management of radioactive waste. A final goal of decommissioning is to enable the partial or complete removal of regulatory control from the facility.

7.57 Decommissioning of nuclear facilities comprises:

(a) Design considerations and early decommissioning planning;

(b) Preparation and approval of the final decommissioning plan;

(c) The actual conduct of decommissioning;

(d) The management of waste resulting from decommissioning activities;

(e) Release of the site for unrestricted or restricted use.

7.58 The key elements that should be considered for the decommissioning of facilities for the predisposal management of radioactive waste, as specified in Ref. [18], include:

(a) The selection of a decommissioning option in which the radionuclides in the residual waste, technical factors, costs, schedules and institutional factors are taken into account;

(b) The development of a decommissioning plan;

(c) The specification of the critical tasks involved in their decommissioning; in particular decontamination, dismantling, demolition, surveillance and conducting a final radiological survey;

(d) The management functions important for their decommissioning, such as training, organizational control, radiological monitoring, planning and the control of waste management, physical protection, safeguards and quality assurance.

7.59 Both the design and operational aspects that will have an influence on decommissioning safety (e.g. the chemical processes or mechanical processes involved) should be duly considered so as to facilitate the eventual decommissioning of a facility. The design considerations for decommissioning and the decommissioning measures should be consistent with the hazards expected to be associated with the facility.

7.60 An initial version of the decommissioning plan should be prepared during the design of the facility in accordance with requirements and recommendations on decommissioning [17, 18].

7.61 During the operation of the facility, the initial decommissioning plan should be periodically reviewed and updated and should be made more comprehensive with respect to:

(a) Technological developments in decommissioning;

(b) Possible human induced accidents and other incidents and natural events;

(c) Modifications to systems and structures affecting the decommissioning plan;

(d) Amendments to regulations and changes in government policy;

(e) Cost estimates and financial provisions.

7.62 A comprehensive decommissioning strategy should be developed for sites also having other facilities to ensure that interdependences are taken into account in the planning for individual facilities [18].

7.63 Even when the bulk of the residual process material has been removed, a significant amount of contaminated material may remain. The expeditious removal of this material should be considered, as it would reduce the need for monitoring and surveillance. Other activities associated with decommissioning may be conducted concurrently with the removal of this material, but the potential for adverse interaction between concurrent activities should be identified and assessed.

7.64 Dismantling and decontamination techniques are required to be chosen such that generation of waste and airborne contamination are minimized and protection of workers and the public is optimized [18].

7.65 Before a site is released, for example for unrestricted use, it should be monitored and, if necessary, cleaned up [34]. A final survey should be performed to demonstrate that the end point conditions, as approved by the regulatory body, have been met.

APPENDIX 1. KEY PROPERTIES AND CHARACTERISTICS OF SPENT NUCLEAR FUEL DECLARED AS WASTE

Key properties and characteristics of unconditioned and conditioned spent fuel are given in the following table.

Properties and characteristics	Unconditioned spent fuel	Conditioned spent fuel
Fuel data: type, power history, initial fissile content, burn-up and cooling time	√	√
Activity: β–γ and a activity by radionuclide for the major contributors to activity	√	√
Criticality safety: geometrical configuration, concentration and inventory of fissile material (e.g. U-233, U-235, Pu-239, Pu-241), presence of neutron poisons and demonstration of non-criticality	√	√
Dose rate: neutron and γ dose rate at the surface and at a distance of 1 m	√	√
Surface contamination: levels of β–γ and α contamination		√
Thermal properties: thermal power, thermal conductivity and predicted maximum temperatures (with and without cooling by engineered systems)	√	√
Chemical properties: pH, main chemical species and compounds, toxic substances and corrosive compounds	√	
Physical properties: density	√	
Mass of waste and/or waste package: total mass (mass of waste form and canister, if applicable)	√	√
Quality of canister/container: material specification, tare weight, dimensions, corrosion resistance, quality of seal weld, material certifications from manufacture; quality assurance records from conditioning process; compatibility with the waste form		√
Stackability and handling: number of packages stackable without deformation, results of package drop tests and requirements for lifting packages		√

(e.g. lifting features)		
Package labelling: unique permanent identification		√
Quality of matrix material: certification and quality assurance records for matrix material		√
Mass fractions of waste form: fractions of waste, fixation materials and additives (to be within specified limits)		√
Stability of the package: corrosion and/or leaching behaviour in relevant atmospheres or aqueous solutions, data on long term corrosion and data extrapolation, influence of surface area and solubility of radionuclides in relevant aqueous solutions	√	√

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ANNEX 1. FACILITY SPECIFIC WASTE MANAGEMENT PROGRAMME

The content of a facility specific waste management programme could include:

(a) The description of the processes in which the radioactive waste is generated by the facility;

(b) A description of the radioactive waste streams and the efforts to avoid and minimise them;

(c) A comprehensive list of waste categories and anticipated arisings and inventories, including historic and legacy waste;

(d) Definition of the facility specific waste management principles and objectives;

(e) Identification of waste management options and associated steps as well as interdependencies between waste management steps;

(f) Justification of the selection of appropriate management options based on the above and international good practices;

(g) Demonstration that the facility specific waste management programme is compatible with national policy and strategy;

(h) Demonstration, if necessary, of how the safety case is affected by the waste management programme, e.g. modification of the programme to incorporate longer storage than originally designed for would be a safety case impact.

The programme should include provisions for:

(a) Keeping the generation of radioactive waste to the minimum practicable, in terms of both activity and volume, by using suitable technology;

(b) Possible reuse and recycling of materials;

(c) Appropriate classification and segregation of waste, and maintenance of an accurate inventory for each radioactive waste stream, with account taken of the available options for clearance and disposal;

(d) Collection, characterization and safe storage of radioactive waste;

(e) Adequate storage capacity for the radioactive waste expected to be generated;

(f) Ensuring that the radioactive waste can be retrieved at the end of the storage period;

(g) Treating, retreating and conditioning radioactive waste to ensure safe storage and disposal;

(h) Safe handling and transport of radioactive waste;

(i) Adequate control of discharges of effluents to the environment;

(j) Monitoring of sources (of effluent discharges) and the environment, for the demonstration of regulatory compliance;

(k) Maintaining facilities and equipment for the collection, processing and storage of waste to ensure safe and reliable operation;

(l) Monitoring the status of the containment for the radioactive waste in the storage location;

(m) Monitoring changes in the characteristics of radioactive waste by means of inspection and regular analysis, in particular, if storage is continued for extended periods;

(n) Initiating, as necessary, research and development activities to improve existing methods for processing radioactive waste or to develop new

(o)techniques and to ensure that suitable procedures are available for the retrieval of stored radioactive waste;

(p)Adoption and implementation of corrective actions on the basis of the results of monitoring.

ANNEX 2. DEVELOPMENT OF SPECIFICATIONS FOR WASTE PACKAGES

Specifications for conditioned radioactive waste are established to ensure that the waste package satisfies the relevant acceptance criteria for transport, storage or disposal. The radiological characteristics (radionuclide concentrations, activity and dose rate) of the waste are the most important ones and are identified at an early stage. Other waste package specifications may be divided into four main topics: chemical and physical properties, mechanical properties, containment capacity and stability. This last topic, 'stability', concerns the capacity of the waste package to retain radionuclides over extended periods of time.

CHEMICAL AND PHYSICAL PROPERTIES

The chemical and physical properties of the waste form include:

(a) Its chemical composition;

(b) Its density, porosity, permeability to water and permeability to gases;

(c) Its homogeneity and the compatibility of the waste with the matrix;

(d) Its thermal stability;

(e) The percentage of water incorporated, exudation of water under compressive stress, shrinkage and curing;

(f) Its leachability and corrosion rate.

The chemical and physical properties of the container include:

(a) Its materials;

(b) Its porosity, permeability to water and permeability to gases;

(c) Its thermal conductivity;

(d) Its solubility and corrosion in corrosive atmospheres or liquids such as water or brines.

The physical properties of the waste package include:

(a) The number of voids in the container (which are to be minimized);

(b) The characteristics of the lidding and sealing arrangements;

(c) Its sensitivity to changes in temperature.

MECHANICAL PROPERTIES

The mechanical properties of the waste form include its tensile strength, compressive strength and dimensional stability.

The mechanical properties of the waste package include its behaviour under mechanical (static and impact) or thermal loads.

CONTAINMENT CAPABILITY

The containment capability of the waste package concerns:

(a) The diffusion and leaching of radionuclides in an aqueous medium;

(b) The release of gas under standard atmospheric conditions or the conditions for acceptance;

(c) The diffusion of tritium under standard atmospheric conditions or conditions for acceptance;

(d) The capability for the fixation and retention of radionuclides;

(e) The water-tightness and gas-tightness of the package sealing device.

STABILITY

Stability of the waste package concerns:

(a) Its behaviour under temperature cycling;

(b) Its sensitivity to elevated temperatures and behaviour in a fire;

(c) Its behaviour under conditions of prolonged radiation exposure;

(d) The sensitivity of the matrix to water contact;

(e) Its resistance to the action of micro-organisms;

(f) The corrosion resistance in a wet medium (for metal containers);

(g) Its porosity and degree of gas-tightness;

(h) Its potential for swelling due to the internal build-up of evolved gases.

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