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Predisposal Management of Radioactive Waste From Fuel Cycle Facilities

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Draft Safety Guide

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PREDISPOSAL MANAGEMENT OF RADIOACTIVE WASTE
FROM FUEL CYCLE FACILITIES

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1 The nuclear fuel cycle produces a wide range of radioactive waste, including inter-alia: high-level waste (e.g., vitrified waste from spent fuel reprocessing, mixed oxide fuel), intermediate-level waste that typically contains longer-lived radionuclides, and low-level waste. The approach to treating liquid and gaseous waste streams influences the amount of effluent generated for discharge, and the approach to clearance and recycling influences the amount of waste for storage and disposal, with a large influence in the optimization of the overall radioactive waste management process (predisposal and disposal). Thus, a key feature of predisposal radioactive waste management at fuel cycle facilities is the interdependence between the steps of pre-disposal waste management as well as disposal within a national framework of waste management.

1.2 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]. Similar safety aspects and expectations for good practice have been set down in international legal instruments, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) [5].

1.3 Measures to prevent or restrict the generation of radioactive waste have to be put in place in the design of facilities and the planning of activities that have the potential to generate radioactive waste. This recognises that the management of the material that generates radioactive waste is the key to avoiding or minimising quantities produced.

1.4 It may be that not all processing steps are necessary for particular categories of radioactive waste. The type of processing necessary will depend on the particular categories of waste, its form and characteristics, and the overall approach to its management, including consideration of the generation of secondary waste. Where appropriate, the waste material resulting from the pre-treatment and treatment may be reused or recycled, or cleared from regulatory control in accordance with national regulations. Such activities limit the eventual challenge associated with waste management. The remaining radioactive waste from all sources that is not cleared, discharged or reused needs to be managed safely over its entire lifetime. Lifetimes of certain waste streams are such that management may fall outside the ability of the operator to deliver or may be dictated by the availability of national assets (e.g. deep geological repository).

1.5 GSR Part 1 [2] requires the government to make provision for the safe management and disposal of radioactive waste arising from facilities and activities. These provisions should be included as essential elements of the governmental policy and the corresponding strategies over the lifetime of facilities and the duration of activities. Importantly there is also a requirement for the government to enforce continuity of responsibility between successive authorized parties.

1.6 In some instances there are several potentially conflicting demands in the predisposal management of the waste that need detailed consideration to determine the optimal integrated solution. Such considerations include the balancing of exposures of workers and/or those of members of the public, the short term and long term risk implications of different waste management strategies, the technological options available and the costs.

1.7 To select the most appropriate type of pretreatment, treatment and conditioning for the radioactive waste when no disposal facility has been established, assumptions have to be made about the likely disposal option. It is necessary to address the interdependences and the potential conflicts between the operational demands of each of the various steps in waste management, while ensuring that the waste is contained and stored in a passive, safe condition. In striking a balance between choosing an option and retaining flexibility, it is important to ensure that safety is not compromised.

OBJECTIVE

1.8 The objective of this Safety Guide is to provide up-to-date recommendations on the predisposal management of radioactive waste generated by fuel cycle facilities, both within larger facilities and at separate, dedicated waste management facilities (including centralized waste management facilities).

1.9 This Safety Guide supersedes those parts of the following safety standards that are concerned with the management of radioactive waste from fuel cycle facilities: Safety Guides WS-G-2.5, Predisposal Management of Low and Intermediate Level Radioactive Waste and WS-G-2.6, Predisposal Management of High Level Radioactive Waste.

1.10 The Safety Guide presents guidance and recommendations on how to meet the requirements established in the following IAEA Safety Requirements publications: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (BSS) (GSR Part 3), [3]Safety of Predisposal Management of Radioactive Waste (GSR Part 5) [4], Nuclear Fuel Cycle Facilities (NSR Part 5) [6], Safety Assessment for Facilities and Activities (GSR Part 4) [7], and The Management System for Facilities and Activities (GS-R-3) [8].

SCOPE

1.11 This Safety Guide covers the predisposal management of radioactive waste generated by fuel cycle facilities that may be managed within larger facilities or at separate, dedicated waste management facilities (including centralized waste management facilities).

1.12 This Safety Guide applies to the predisposal management of radioactive waste of all types and covers all steps in the management of radioactive waste, from its generation up to disposal, including its processing (pretreatment, treatment and conditioning), storage and transport. A classification scheme for radioactive waste and recommendations on its application to the various types of radioactive waste are provided in General Safety Guide GSG-1. [9].

1.13 Storage of radioactive waste and storage of spent nuclear fuel are not dealt with in detail in this Safety Guide. These are dealt with in Safety Guide WS-G-6.1, Storage of Radioactive Waste [10] and SSG-15 [11]. Transport of radioactive waste must comply with TS-R-1 [12] and is not dealt with in detail in this Safety Guide. Spent fuel that is transferred to reprocessing facilities is not regarded as radioactive waste.

1.14 This publication is primarily targeted at complex situations that are typical in facilities for the predisposal management of radioactive waste arising from the nuclear fuel cycle and those wastes arising from facilities associated with medical isotopes produced from irradiation of nuclear materials. However, the regulatory body should consider a graded approach to the application of the requirements for the predisposal management of radioactive waste, taking account of the hazards, the complexity of facilities and activities, and the characteristics of the waste, and should apply the requirements as necessary and appropriate.

1.15 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.

1.16 The Safety Guide does not provide comprehensive and detailed recommendations on physical protection of nuclear material and nuclear facilities. Recommendations and guidelines on physical protection arrangements at nuclear facilities are provided in INFCIRC/274 and INFCIRC/225 [13, 14] and in publications in the IAEA Nuclear Security Series. The Safety Guide considers physical protection and accounting and control of nuclear material only to highlight their potential implications for safety.

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 SF-1 [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. This includes 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 populations remote from the present facilities or activities) and the environment.

2.3 Safety Requirement NS-R-5 [6] and GS-R-3 [8] provide requirements on management system for both the regulatory body and the operator 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 the context of fuel cycle facilities, the control of events initiated by chemical hazards can have a significant bearing on achieving the fundamental safety objective. Events initiated by chemical hazards are required to be considered in the design, commissioning and operation of the facility. Activities at fuel cycle facilities may also include industrial processes that pose additional hazards to site personnel and the environment.

2.5 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 people of present and future generations and populations remote from present facilities and activities that give rise to radiation risks (SF-1) [1].

RADIATION PROTECTION

2.6 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].

2.7 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.

2.8 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 [7]. 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 [7]. They include management and technical requirements to prevent the occurrence of incidents or accidents and provisions for mitigating their consequences if they do occur.

2.9 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 dispersal of radionuclides in the environment and potential exposure that could arise in the future from the disposal of radioactive waste (SF-1, ICRP 77, ICRP 81) [1, 15, 16].

2.10 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 TSR-1 [9].

ENVIRONMENTAL CONCERNS

2.11 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 (SF-1, BSS) [1, 3].

2.12 As stated in NS-R-5 [6] 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".

2.13 Thus the requirements for delivering environmental protection are significantly connected with those associated with the predisposal management of radioactive waste.

2.14 NS-R-5 [6] further states that 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 discharges 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 (optimisation of protection).

2.15 Clearance from regulatory control and control of discharges are addressed in IAEA Safety Standards Series Nos. RS-G-1.7 and WS-G-2.3 [17, 18] 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 [2, 4]. 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 interdependencies between the various stages 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 [5].

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, adjacent to a facility site, of installations that could prejudice the safety of the facility is required to be monitored and controlled by means of planning requirements or other legal instruments.

3.5 The management of radioactive waste may entail the transfer of radioactive waste from one operating organization to another organization and also from one national or governmental entity to another. Such transfers create interdependencies between organizations 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 (GSR Parts 1 and 5) [2, 4].

3.7 Responsibility for safety should be ensured by means of a system of authorization by the regulatory body. For transfers between States, authorizations from the respective national regulatory bodies are required (GSR Parts 1 and 5) [2, 4].

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 licensing 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 storage management facility or early dispatch of the waste to a disposal facility.

3.10 The government should consult interested parties (i.e. those who are involved in or are affected by radioactive waste management activities) on matters relating to the development of policies and strategies that affect the management of radioactive waste.

3.11 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.

3.12 In order to facilitate the establishment of a national policy and strategy, the Government should establish a national inventory of the radioactive waste (actual and expected, such as waste generated during decommissioning and dismantling of facilities) and update it at regular time intervals. This inventory should take into account the guidance in GSG-1 [9].

3.13 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.

3.14 The national policy and strategy should address the various waste classes as identified in GSG-1 [9] and their long-term management, from a technical point of view as well as from a resources point of view. It should take due account of the concerns of the public including populations remote from present facilities and activities.

3.15 As far as possible, the 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 The regulatory review of the decommissioning plans for radioactive waste management facilities should follow a graded approach, particularly considering the phases in the lifetime of the radioactive waste management facility or activities. 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 identification and availability of the necessary information, including records from the design, construction and operational phases will be ensured for when the decommissioning takes place.

3.18 The decommissioning plan should be updated regularly by the licensee and updates should be reviewed by the regulatory body. If a facility is shut down and no longer to be used for its intended purpose, a final decommissioning plan should be submitted to the regulatory body for review and approval (where appropriate within the legal framework).

3.19 General recommendations for regulatory inspection and enforcement actions relating to radioactive waste management facilities are provided in GS-G-1.3 [19]. 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, compliance with acceptance criteria 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 facility and audits of the operating organization. The regulatory body

[1] The safety case is a collection of arguments and evidence in support of the safety of a facility or activity. This collection of argument 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).

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 [20].

3.20 The regulatory body should set up appropriate means of informing interested parties, such as persons living in the vicinity, the general public, information 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.

3.21 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 facility, which encompasses the whole anticipated operating period, including periodic review of safety cases and safety assessments, as elaborated in Section 5; or

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

3.22 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 co-ordinated in order to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operating organisation. The regulatory functions of authorisation, 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.

3.23 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.

3.24 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 of 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.

3.25 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.

3.26 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 radiological safety and environmental assessments in support of the application for a licence and conducting periodic safety reviews;

(c) Operation of 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 and any events that occur at the facility and which have to be reported to the regulatory body) and communicating with relevant interested parties and the general public including those who are remote from the facilities 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 in compliance with 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.

3.27 In case 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 applicable to predisposal waste management:

(1) waste prevention

(2) re-use

(3) recycling

(4) processing and disposal

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

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 WSR-5 [21] and recommendations are provided in WS-G-2.4 [22].

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 concerned staff members understand to their required level, the safety case, the nature of the radioactive waste, its potential hazards and the relevant operating and safety procedures. 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 assessment/case 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 dispositions to other facilities should be documented and such documents 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 (See Chapter 7).

3.36 The operating organization should establish a process for authorization that 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 which is commensurate with the 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 (GSR Part 1) [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 programme. 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 (GS-R-2) [22] and should be prepared to respond to accidents at all times as indicated in the emergency plans (See Chapter 7).

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 (sealed or non-sealed) and activity of the source, and also on the step in the predisposal management. As a facility moves through the phases of 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 processes 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 whilst implementing them. E.g. implementation of a security system should be carried out such that the operator is not prevented from carrying out an operation less safely.

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 A key feature of pre-disposal radioactive waste management within fuel cycle facilities is the nature of their interdependence and often their place within a national framework of pre-disposal waste management. Such interdependencies create safety case interfaces. The information that crosses these interfaces including waste acceptance criteria and limits and conditions must be demonstrated to be carefully managed along with any deviations that might occur for instance associated to those uncertainties.

4.10 Thus it important to highlight that the interdependencies should be taken into consideration such to ensure that an integrated approach to safety is adopted; and that safety (within a waste management framework that also takes into consideration waste minimisation via adoption of the waste management hierarchy) is optimized.

4.11 Compatibility of the waste packages and unpackaged waste with a disposal option should be demonstrated; however, in the event that a disposal option has not been identified at a certain stage, assumptions should be made about the likely disposal options and these should be set down clearly.

4.12 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 the selected or anticipated disposal option. In addition, 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 waste disposal programme is developed.

4.13 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.

4.14 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.

4.15 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.

4.16 The requirements on management systems for all stages in the lifecycle of a predisposal radioactive waste management facility are established in GS-R-3 [6]. General guidance on the management systems for facilities and activities is given in Ref. [24], while specific recommendations on management systems related to the predisposal management of radioactive waste are provided in GS-G-3.3 [25].

4.17 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. Examples are provided in Annex 2.

4.18 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.

4.19 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.

4.20 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

4.21 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.

4.22 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

4.23 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 provisions 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

4.24 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.

4.25 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).

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

4.27 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.

4.28 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 [5]. Requirements for the safety case and safety assessment for radioactive waste management facilities and activities are set in GSR Part 5 [1]. 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) [25].

5.3 Prior to authorization of a radioactive waste management facility, the operating organization should provide the regulatory body with a safety case 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 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.

5.4 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 for predisposal waste management facilities 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 should include identification of uncertainties in the performance of the facility, 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 safety cases.

5.7 As stated in DS284, compliance with the requirements for the documentation of a safety case presents a number of challenges; for example, due to the target audience being composed of a wide range of interested parties with different needs, expectations and concerns, as well as due to situations in which there are complex legal and regulatory requirements involving multiple regulatory agencies with different regulatory processes and where multiple levels of documentation are required. It should be noted that the regulatory authorities involved in the authorisation of nuclear fuel cycle facilities are often larger in number due to the greater scope of safety concerns, for example, the management of large quantities of toxic and reactive chemicals.

5.8 As indicated in [25], the documentation of the safety case should cover at a minimum the safety assessment and the operating limits and conditions. There are a number of common elements that should be considered. These should include: the executive summary, the introduction and context for the safety case (or safety assessment), the strategy for safety, the safety assessment, synthesis and conclusions, a statement of confidence, and a plan for follow-up programmes and actions, as well as a summary of public involvement in development of the safety case.

5.9 Although the focus of this Safety Guide is on radiological safety, non-radiological hazards (e.g. chemo-toxic, industrial) should also be addressed as specified in national requirements or as they may affect radiological safety (e.g. fires). Non-radiological hazards for which safety criteria exist can be assessed and modelled along with radiological hazards (e.g. hazards associated with the lifting and handling of waste containers).

5.10 The recommended approach to safety assessment includes the following key components:

(g) Specification of the context for the assessment;

(h) Description of the predisposal waste management facility or activity and the waste;

(i) Development and justification of scenarios;

(j) Formulation of models and identification of data needs;

(k) Performance of calculations and evaluation of results;

(l) Analysis of safety measures and engineering aspects, and comparison with safety criteria;

(m) Independent verification of the results;

(n) Review and modification of the assessment, if necessary (i.e. iteration).

5.11 These are described in more detail below. Examples of hazards related to the waste materials and characteristics for particular fuel cycle facilities are identified within Appendix 1. Examples of hazards associated with specific waste management activities are identified within Appendix 2. Examples of “generic” waste and activities encountered within most fuel cycle facilities are identified within Appendix 3. These tables are not exhaustive and the assessment should identify where other specific hazards are enveloped within its pre-disposal waste management safety case and assessment.

SPECIFICATION OF THE CONTEXT FOR THE ASSESSMENT

5.12 The context for assessment involves the following key aspects: the purpose of the assessment, the philosophy underlying the assessment, the regulatory framework, the assessment end points, and the time frame for the assessment.

5.13 In addition to the general aspects individual fuel cycle facilities need to identify the envelope of the predisposal waste management assessment within the context of an operating plant. Particularly where the operating plant is not a waste plant but is generating wastes as a consequence of that processing it is important to identify the point at which the pre-disposal waste management begins. Appendix 1 column 3 identifies examples of such activities.

DESCRIPTION OF THE PREDISPOSAL WASTE MANAGEMENT FACILITY OR ACTIVITY AND THE WASTE;

5.14 It is important to recognise that the description of the facility is the basis from which the quantification and nature of the hazards may be determined (e.g. management of natural Uranium versus irradiated materials).

5.15 Quantities, chemical and radiological characteristics of waste are important in quantifying the hazard and defining the challenge of the waste management but can be very facility specific and thus should be considered in the decision making process as part of a graded approach.

DEVELOPMENT AND JUSTIFICATION OF SCENARIOS;

5.16 Scenarios within FCF’s should cover a range of situations arising either during the normal operation of a facility or as a consequence of a specific event leading to a deviation from normal operation conditions.

5.17 The set of safety assessment scenarios should take account of all relevant existing and potential hazards arising for the facility or activity, and their interrelation and evolution over the lifetime of the facility or activity according to the safety case and the context for the assessment.

5.18 As basis of the development and justification of scenarios, a systematic approach to identification and screening of hazards should be taken on the basis of the description of facility and the activities. The following steps should be applied in an iterative manner in order to identify scenarios for normal operation and anticipated operational occurrences and accident conditions that could lead to the exposure of workers and members of the public, or adversely impact the environment:

(a) Identification of hazards and initiating events: This should consider the inventory, activity, physical conditions and location of the waste and other radioactive material, together with any additional hazards arising from activities or processes for its management, and should identify where initiating events create the potential for causing harm to human health and/or the environment;

(b) Screening of hazards: The hazards and initiating events identified should be quantified and screened in order to direct efforts toward all significant and relevant hazards and initiating events for the facility or activity;

For individual fuel cycle facilities the decision making process should identify the screening criteria specific to its operations and materials based on safety and environmental limits set down for that facility.

(c) Identification of scenarios: The safety analysis should identify all relevant scenarios arising from either processes or accident situations in which the screened hazards could be realized. The general methodologies for identifying such scenarios are applicable for fuel cycle facilities. Greater attention should be paid however to the facilities and processes that involve significant chemical and physical processing, material transfer and human intervention.

The process of identification and screening of hazards should consider the complexity of the facility or activity, as well as the evolution of hazards and risks over the lifetime of the facility or activity, and should be consistent with the regulatory framework.

FORMULATION OF MODELS AND IDENTIFICATION OF DATA NEEDS

5.19 The broad range of methods and models required to assess the safety of pre-disposal waste management activities require a wide range of data inputs. Such data needs to be justified especially when considering the wide range of activities within fuel cycle facilities.

5.20 As pre-disposal waste management within fuel cycle facilities is often a flow process with materials transferring directly from step to step it is important to recognise the interdependencies of these when considering data and models and their inputs and outputs.

5.21 Some iteration of the above steps will be required to reflect progressive development of the safety assessment and evolution of the waste management process(es).

PERFORMANCE OF CALCULATIONS AND EVALUATION OF RESULTS;

5.22 Once the models have been parameterized they can be used for performing deterministic and/or probabilistic calculations for the assessment cases corresponding to the different scenarios.

5.23 The assessment cases should adequately address the appropriate scenarios using the conceptual models and site and facility or activity design information. A sufficient range of sensitivity and uncertainty analyses should be performed to contribute to understanding of the system and to identify parameter correlations that have not been treated in an appropriate way.

CENTRALISED WASTE MANAGEMENT FACILITIES

5.24 In the case of centralised waste management facilities where one or more waste streams are received from separate sources the assessment should:

(a) Be carried out for all waste categories received and activities related to their specific processing

(b) Have regard to areas within the facility where there is a potential for individual wastes to interact

(c) Identify safety measures and engineering aspects for each waste category

(d) Review and consolidate the safety measures to determine the optimum safety measures and engineering aspects for the safety case for the overall facility. Optimisation should ensure no conflicts or duplications occur.

(e) Identify consolidated operating limits and conditions as a basis for safe operation and to ensure compliance with the safety criteria

6. GENERAL SAFETY CONSIDERATIONS

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 the waste acceptance criteria have to be demonstrated. Therefore the waste has to be categorised and characterised 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 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 in the future at a disposal facility 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. Transport of radioactive waste must comply with TS-R-1 [9] and is not dealt with in detail in this Safety Guide. Guidance on transport of radioactive waste can be found in TS-G-1.1 [26].

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 to both the 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 that 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 recycle 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, in order to minimize the generation of secondary radioactive waste. 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. For the qualification of a conditioning process the programme should be designed in such a way that the number of test specimens using actual radioactive waste is minimized.

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.

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

6.13 Requirement 8 of the BSS [7] 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.

6.14 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.

6.15 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) [27].

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.

6.16 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 waste.

6.17 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

6.18 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.

6.19 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, including modelling, 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.

6.20 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 at the repository site and to the characteristics of the radioactive waste and the engineered components of the disposal facility.

6.21 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.

6.22 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.

6.23 Details of the purpose, methods and approaches to the classification of radioactive waste are provided in GSG-1 [8]. Annex III of [8] also provides information on origin and types of radioactive waste, including waste from nuclear power production. It must be noted that the classification scheme is based on the long-term management (disposal) of the radioactive waste.

6.24 It should be borne in mind that most radioactive waste contains alpha emitting radionuclides. Inflammable, pyrophoric, corrosive or other hazardous materials should also be given special attention. Care should be taken to avoid mixing waste of these types.

6.25 Liquid radioactive waste, which is mainly water based, should be classified for processing purposes according to its activity concentration levels and its content of chemical substances. For instance, radioactive waste containing organic matter may need special treatment. Non-aqueous radioactive waste such as oil should be segregated for separate treatment.

6.26 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.

6.27 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

6.28 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.

6.29 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 in the future at a repository in order to provide guidance for its predisposal management.

6.30 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

6.31 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.

6.32 The first operation in the pre-treatment of radioactive waste is to collect waste radioactive 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 discharged, either directly or after allowing for a decay period.

6.33 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.

6.34 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.

6.35 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.

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

6.37 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, especially the unplanned release of volatile radionuclides or radioactive aerosols. 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

6.38 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);

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

(d) Change of the properties of the waste.

SOLID WASTE

6.39 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.

6.40 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.

6.41 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. It should be noted, that incineration will result in the increase of the activity concentration levels which might result in a change of the waste class. 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 and concentration in residues of the gas cleaning system and those remaining in the ash, and to their further conditioning.

6.42 Releases of radionuclides to the environment are largely determined by the operational conditions of the incinerator, in particular through control of the temperature and the types and amounts of waste incinerated and its radionuclide content. 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.

6.43 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.

6.44 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.

6.45 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.

6.46 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 (DS407) [28].

6.47 Where applicable spent ion exchange resins are usually flushed out as a 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.

6.48 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.

LIQUID WASTE

6.49 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.

GASEOUS WASTE

6.50 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.

6.51 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.

CONDITIONING

6.52 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).

6.53 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.

6.54 Liquid waste is often converted into a solid form by solidifying it in a suitable matrix such as cement, bitumen or polymer for low- and intermediate-level waste or glass for high-level waste. Solidification may also be achieved without a matrix material, for example by drying. The product is then enclosed in a container.

6.55 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.

6.56 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.

6.57 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.

6.58 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 container 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.

6.59 If there may be a significant delay before an acceptable disposal route becomes available, the container 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.**

6.60 Storage of radioactive waste is dealt with extensively in WS-G-6.1 [29].

Requirement 12: Radioactive waste acceptance criteria **Waste packeges an unpacked waste that are accepted for processing, storage and/or disposal shall conform to criteria that are consistent with the safety case.**

6.61 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 criteria 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 criteria should be anticipated as far as possible. The waste acceptance criteria may be met by providing an overpack that is tailored to the specific conditions at the repository site and to the characteristics of the waste and the engineered components of the disposal facility. Annex 3 provides a listing of the typical properties and characteristics that should be considered for waste packages in the predisposal management of radioactive waste.

6.62 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.

6.63 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.

6.64 Identification of waste acceptance criteria enable the effective interlinking of facilities and processes where material is transferring, being held for interim storage or transported to final disposal

6.65 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 for siting and methods that could be used in a graded approach in the siting of nuclear installations are dealt with in NS-R-3 [30], SSG-9 [31] and SSG-18 [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 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) Protection against radiation exposure (by shielding and containment);

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

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

(d) Waste characterization and inventory control;

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

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

(g) The control of liquid and gaseous effluents;

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

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

(j) Maintenance work and eventual decommissioning;

(k) Fire protection and the prevention of explosions;

(l) The prevention of criticality;

(m) Access controls and controls for the physical 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 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 [28].

7.16 The design of a facility for the predisposal management of high-level (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 the forced circulation of coolant is used, the system should be highly reliable. Examples of features that enhance the reliability of the cooling system 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 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, directions of rotation, directions of flow, currents, interlocks, etc., 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 the is 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 including waste management requirements for facility operation apply. Active commissioning should involve 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 (GS-G-3.3) [24].

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 (GS-G-2.1) [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 that need to be available 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 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 in TSR-1 [9], because the 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. Provision should be made 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 WS-R-5 [20], 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 (WS-R-5, WS-G-2.4) [20, 21].

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 (WS-G-2.4) [21].

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 (WS-R-5) [20].

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

APPENDIX 1: EXAMPLES OF SPECIFIC WASTE RELATED SAFETY CONSIDERATIONS

Column1	Column2	Column 3	Column 4	Column 5	Column 6	Column 7
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Waste materials (these materials can be subdivided into one or more waste categories)**	**Characteristics to be considered**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
Uranium conversion (natural)	Chemical processing of uranium concentrates from mining operations are purified and converted to UF6 for onward processing	• Post Dissolution insoluble solids treatment • Solvent washing effluent management • Fluoride related gaseous scrubbing particulate scrubbing • Particulate filtration • Scrubber Liquid effluent management • General Solid waste management including collection, size reduction and packaging	• UOC insolubles	• U and NORM concentration • U compound properties • Impurities (e.g. V, Cr)	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
			• Uranium unburns/ Fluoride ash	• Concentration of short lived daughters (Th, Pa) • U Concentration • Uranium compound properties • Fluorine content • Particulate size and dispersibility • Temperature and thermal capacity	• Alpha bearing materials Radiological dose (internal/External) • Additional beta dose rates due to concentration of short lived radionuclides)	• Fire • Fluoride toxicity (acute/chronic) • Heavy metal toxicity • Thermal burns
			• KOH liquors including test liquors	• Liquids containing uranium and fluorides and alkali chemicals • Low uranium concentration	Uranium impact on environment	• Alkali and fluoride chemical handling • Chemical impact on environment • Chemical impact on operators

Column1	Column2	Column 3	Column 4	Column 5	Column 6	Column 7
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Waste materials (these materials can be subdivided into one or more waste categories)**	**Characteristics to be considered**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
			• Carbonate and hydroxide liquors from solvent washing including test liquors	• Contamination with solvent • Possible colloids formation • U compound properties • Impurities (e.g. V, Cr) • Variable concentrations of test chemicals and uranium and daughter products	Uranium and daughter product impact on environment	• Alkali and fluoride chemical handling • Chemical impact on environment Solvent impact on environment • Chemical impact on operators
			• PPE and other compressible solids	• Varying levels of Surface contaminated materials	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
			• Contaminated filters	• Varying levels of activity • Uranium • Uranium compound properties	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
			• Non-ferrous and ferrous Metals components	• Varying levels of activity • Uranium • Uranium compound properties	• Alpha bearing materials • Radiological Dose (internal/external)	• Heavy metal toxicity • Environmental impact

Column1	Column2	Column 3	Column 4	Column 5	Column 6	Column 7
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Waste materials (these materials can be subdivided into one or more waste categories)**	**Characteristics to be considered**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
			• Organic / plastic process components e.g. PTFE	• Varying levels of activity • Uranium • Uranium compound properties • Impurities of organics	• Alpha bearing materials • Radiological Dose (internal/external)	• Fire • Heavy metal toxicity • Hydrogen Fluoride • Fluorine
			• Contaminated electrolyte	• Uranium • Uranium compound properties • HF/KF electrolyte in solid and liquid forms • Gaseous HF • Fluorine • hydrogen	Potential of exposure to :- • Alpha bearing materials • Radiological Dose (internal/external)	• Fire and explosion • Heavy metal toxicity • Hydrogen Fluoride • Fluorine • Fluoride toxicity (acute/chronic) • Heavy metal toxicity • Chemical burns
			• Non-compressible Solids e.g. building rubble	• Varying levels of activity concentration levels	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
			• Organic Liquids e.g. Kerosene, TBP	• Varying levels of activity • Uranium • Uranium compound properties • Organic properties	• Alpha bearing materials • Radiological Dose (internal/external) • Environmental impact	• Fire • Heavy metal toxicity • Environmental impact

Column1	Column2	Column 3	Column 4	Column 5	Column 6	Column 7
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Waste materials (these materials can be subdivided into one or more waste categories)**	**Characteristics to be considered**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
			• Gases and aerosols	• Varying levels of activity e.g. uranium, uranium daughter products and their compounds • Varying levels of chemical composition e.g. UF6 , UO2F2, HF, F2, NH3	• Alpha bearing materials • Radiological Dose (internal/external) • Environmental impact	• Heavy metal toxicity • Environmental impact
Uranium Enrichment (centrifuge)	Receipt of Uranium Hexafluoride, vaporization, enrichment, sublimation, liquefaction and freezing for dispatch to storage or fuel production plant	• Particulate filtration • Hex Cylinder decontamination • Waste Hex cylinder size reduction • General Solid waste management including collection, size reduction and packaging • General liquid waste management e.g. cooling water, steam condensates disposal • Refrigerants and glycol disposal	Used Cylinders including those requiring long term management prior to disposal	• Varying levels of activity from buildup of uranium and uranium daughter products and impurities • Potential for presence of residual washings • Potential for unknown contents both mass and composition • Hydrogen • HF	• Alpha bearing materials • Radiological Dose (internal/external) • criticality • Environmental impact	• Heavy metal toxicity • Corrosive chemicals • Explosion • overpressurisation • Environmental impact
			Spent cylinder washings	• Varying levels of activity from buildup of uranium and uranium daughter products and impurities	• Alpha bearing materials • Radiological Dose (internal/external) • criticality	• Heavy metal toxicity • Corrosive chemicals • Explosion • overpressurisation Environmental impact

Column1	Column2	Column 3	Column 4	Column 5	Column 6	Column 7
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Waste materials (these materials can be subdivided into one or more waste categories)**	**Characteristics to be considered**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
				• Variable and potential unknown chemical composition • Hydrofluoric acid content	• Environmental impact	
			Cooling water and condensates	Potential uranium contamination	• Alpha bearing materials • Radiological Dose (internal/external)	• Heavy metal toxicity • Environmental impact
			Ferrous and non-ferrous metals	• Varying levels of activity • Uranium	• Alpha bearing materials • Radiological Dose (internal/external)	• Heavy metal toxicity • Environmental impact
			PPE and other compressible solids	• Varying levels of Surface contaminated materials	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
			Gases and aerosols	• Varying levels of activity • Varying levels of chemical composition e.g. UF_6 , UO_2F_2, HF	• Alpha bearing materials • Radiological Dose (internal/external) • Environmental impact	• Heavy metal toxicity • Environmental impact
			Process filters	• Varying levels of activity • Uranium	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
			Particulate filtration	• Varying levels of activity • Uranium	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity

Column1	Column2	Column 3	Column 4	Column 5	Column 6	Column 7
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Waste materials (these materials can be subdivided into one or more waste categories)**	**Characteristics to be considered**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
			Non-compressible Solids e.g. building rubble	• Varying levels of activity concentration levels	• Alpha bearing materials • Radiological Dose (internal/external)	Heavy metal toxicity
Waste Treatment and conditioning plant	Predisposal waste management plant that receives low alpha compactable, solid waste in drums from a medical isotope processing facility and produces waste packages for disposal	• Receiving waste and checking with WAC • Compaction of the received drums • Transfer, sorting and collection of pucks • Drying of pucks • Placement of pucks into waste container • Waste container grouted to produce a waste package	PPE and other compressible solids	• Varying levels of Surface contaminated materials • Potential for release of liquids on compression • Release of gases on compression • Corrosion of dissimilar materials	• Radiological Dose (internal/external) • Environmental impact e.g. Iodine releases	• Potential for chemical toxicity • Potential for chemical reactions • Potential for gaseous corrosion reaction products e.g. hydrogen • Environmental impact

APPENDIX 2: EXAMPLES OF SPECIFIC SAFETY CONSIDERATIONS (FACILITIES PROCESSING RADIOACTIVE WASTE)

Column1	Column2	Column 3	Column 4	Column 5
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
Waste Treatment and conditioning plant	Predisposal waste management plant that receives low alpha compactable, solid waste in drums from a medical isotope processing facility and produces waste packages for disposal	• Receiving waste and verifying WAC including sampling	• External radiation • Internal radiation (via contamination or release)	• Chemical / Toxic materials • Industrial including handling of sharps • Chemical reactions of / between waste compounds • Fragile materials
		• Compaction of the received drums	• External radiation • Internal radiation (via contamination or release) • Release of radioactive liquids including oils • Release of radioactive dusts • Release of radioactive gases	• Generation of liquids • Generation of dusts • Chemical reactions • Pressure bursts • explosions • industrial including handling of sharps

Column1	Column2	Column 3	Column 4	Column 5
Waste Generating Facility/ Waste Processing Facility	**Facility description**	**Waste management Activities associated with the process unit operations of the FCF**	**Hazards to be considered (radiological)**	**Hazards to be considered (non-radiological)**
		• Transfer, sorting and collection and drying of pucks	• External radiation • Internal radiation (via contamination or release)	• Industrial including handling of sharps • Chemical / Toxic materials
		• Placement of pucks into waste container	• External radiation • Internal radiation (via contamination or release)	• Industrial including handling of sharps • Chemical / Toxic materials
		• Waste container grouted to produce a waste package	• External radiation • Internal radiation (via contamination or release)	• Industrial • Chemical materials (grout)
		• Waste package cleaning, Surveillance, Monitor and Transfer to interim Store	• External radiation • Internal radiation (via contamination)	• Industrial

APPENDIX 3: SPECIFIC SAFETY CONSIDERATIONS OF FUEL CYCLE FACILITIES

The following is a list of typical fuel cycle facilities including those which form part of facilities with a purpose other than radioactive waste management. Where appropriate certain features are highlighted that require specific attention when considering radioactive waste management.

This table is not exhaustive. Rather, it provides indicators for the safety assessor to produce the equivalents of the tables in Appendices 1 and 2 for the specific fuel cycle facility under consideration.

NATURAL URANIUM CONVERSION

- Concentrations of Uranium compounds and uranium daughter products as radioactive materials in waste
- Concentrations of Uranium as heavy metals in the waste
- Characteristics of the Uranium compounds e.g. solubility
- Concentrations of contaminant including Chromium and Vanadium in the waste streams
- Chemical corrosive materials e.g. Hydrogen fluoride, sulphuric acid
- Chemical toxic materials e.g. Ammonia
- Fire consideration from reagents including Fluorine and hydrogen
- Chemical processes that generate effluent and gaseous emissions

IRRADIATED URANIUM CONVERSION

- As for Natural Uranium Conversion

  In addition
- Concentration of fission and nuclear reaction products e.g. U232 and Pu isotopes
- Elevated dose rates
- Ingrowth of radionuclides during processing
- Elevated radioactivity concentration levels

URANIUM ENRICHMENT

- Concentrations of Uranium compounds as radioactive materials in waste
- Concentrations of Uranium as heavy metals in the waste
- Characteristics of the Uranium as UF6 and as a soluble compound

- Presence of HF as a reaction product
- Bulk Depleted Uranium generation and accumulation as a corrosive fluoride e.g. (Preference for passive stable uranium storage of depleted uranium for long term management e.g. Uranium hexafluoride versus Uranium Oxide)
- Criticality in waste management processes which include techniques / chemical reactions such as precipitation
- Failure rate of process equipment (Optimising the replacement frequency of enrichment stages where the enrichment stage is a contaminated waste metal)

URANIUM FUEL FABRICATION

- Concentrations of Uranium compounds as radioactive materials in waste
- Concentrations of Uranium as heavy metals in the waste
- Characteristics of the Uranium as UF_6 as a soluble compound
- Characteristics of the uranium as UO_2 as an insoluble compound
- Pyrophoric properties of Uranium metal
- Criticality
- Hydrogen
- Hydrofluoric acid
- High temperature processes
- Maintenance of tight manufacturing tolerances (Operator inspection requirements, fuel manufacturing failures generating waste streams)

MOX FUEL FABRICATION

- Concentrations of Uranium and transuranics as radioactive materials in waste (e.g. americium ingrowth)
- Characteristics of the uranium and transuranics insoluble compounds
- Plutonium physical properties (hardness and ability to act as a grinding medium)
- Radiolytic properties of plutonium (self-heating)
- Plutonium dust and contamination (Importance of maintaining process integrity and cleanliness)
- Criticality
- Hydrogen
- High temperature processes
- Maintenance of tight manufacturing tolerances (Operator inspection requirements, fuel manufacturing failures generating waste streams)

PLUTONIUM HANDLING FACILITIES

- Concentrations of plutonium and plutonium daughter products as radioactive materials in waste (e.g. americium ingrowth)
- Characteristics of the of plutonium and plutonium daughter products insoluble compounds
- Characteristics of the of plutonium and plutonium daughter products soluble compounds
- Plutonium physical properties (hardness and ability to act as a grinding medium)
- Radiolytic properties of plutonium (self-heating, radiolysis of water)
- Plutonium dust and contamination (Importance of maintaining process integrity and cleanliness)
- Criticality
- Hydrogen
- Chemical Reagents (including hydrogen)
- High temperature processes
- Maintenance of tight manufacturing tolerances (Operator inspection requirements, fuel manufacturing failures generating waste streams)
- Chemical processes that generate effluent and gaseous emissions

REPROCESSING

- Radiological characteristics of spent fuel (burnup and cooling, effects on handling equipment)
- Physical characteristics of spent fuel (fragility)
- Concentrations of Uranium and transuranics as radioactive materials in waste
- Characteristics of the uranium and transuranics insoluble compounds
- Concentration of fission and nuclear reaction products
- Elevated dose rates
- Ingrowth of radionuclides during processing
- Elevated radioactivity concentration levels
- Criticality (particularly in effluent precipitation processes and solvent washing)
- Chemical Reagents and reaction products (including hydrogen and NOx)
- High temperature processes
- Chemically Reactive metals (e.g. Zirconium)

- Chemical processes that generate effluent and gaseous emissions

LIQUID WASTE TREATMENT

- Presence of all contaminants as addressed above
- Presence of dissolved contaminants and particulates within liquid streams
- Physical concentration that generates precipitates of radioactive material including fissile material
- Chemical reactions that generate precipitates of radioactive material including fissile material
- Criticality
- Chemical reagent (non-radiological hazards and environmental impact)
- Environmental impact due to discharges
- Generation of secondary waste and their predisposal waste management requirements e.g. accumulation of spent radioactive ion exchange media (elevated external dose rate levels)

GASEOUS WASTE TREATMENT

- Presence of all contaminants as addressed above
- Presence of particulates and aerosols within gaseous effluent streams (Condensation / deposition within gaseous effluent lines)
- Environmental impact due to emissions / discharges (Effective, representative characterisation and monitoring techniques are needed)
- Generation of secondary waste and their pre-disposal waste management requirements e.g. accumulation of used HEPA filters (elevated external dose rate levels), liquid wastes
- Accumulation of short lived isotopes on adsorption media (E.g. Iodine 131 on activated carbon columns)

EVAPORATION AND INCINERATION

- Concentration of radioactive materials including fissile materials within the waste
  -Increased dose rates
  -Criticality
  -Ability to dispose of the material
- High temperatures
- Fire
- Chemical reagents

- Chemical reactions of particularly contaminations or inadvertent arisings (e.g. solvents within aqueous streams)
- Presence of all contaminants as addressed above
- Presence of particulates and aerosols within gaseous effluent streams (Condensation / deposition within gaseous effluent lines)
- Environmental impact due to emissions / discharges (Effective, representative characterisation and monitoring techniques are needed)
- Generation of secondary waste and their pre-disposal waste management requirements e.g. accumulation of used HEPA filters (elevated external dose rate levels), liquid wastes

VITRIFICATION

- Concentration of radioactive materials including fissile materials within the waste
  -Increased dose rates
  -Criticality
  -Ability to dispose of the material
- High temperatures
- Corrosive liquids and vapours (e.g. nitric acid, NOx)
- Chemical reactions of particularly contaminations or inadvertent arisings (e.g. solvents within aqueous streams)
- Presence of all contaminants as addressed above
- Presence of particulates and aerosols within gaseous effluent streams (Condensation / deposition within gaseous effluent lines)
- Environmental impact due to emissions / discharges (Effective, representative characterisation and monitoring techniques are needed)
- Generation of secondary waste with significant radioactivity levels and their pre-disposal waste management requirements e.g. accumulation of used HEPA filters liquid wastes, highly contaminated process equipment - resulting in elevated external dose rate levels)
- Corrosive effects of molten glass (generation of highly contaminated spent melters)

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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 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 plan 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. EXAMPLES OF MANAGEMENT SYSTEM LIFECYCLE PROVISIONS

DESIGN PHASE ASPECTS

Commence when a decision is made to carry out operations involving the management of radioactive materials.

(a) Review of government policies to establish national expectations and fit into national strategic waste strategy

(b) Establish the location of the facility to take into account safety and radioactive waste management aspects i.e. distance from populations centres and availability of transport links from the facility to waste treatment /disposal sites and recognising decommissioning will also impact on populace.

(c) Establish an integrated waste strategy and Integrated Waste Management programme

(d) Establish / upgrade waste management inventory

(e) Establish steps in the management of the radioactive materials and related radioactive wastes.

(f) Evolve the waste management inventory to incorporate all wastes identified

(g) Establish initial waste disposal criteria, onward disposition criteria, storage criteria

(h) Establish links with upstream and downstream facilities

(i) Establish Integrated waste strategy and apply the waste management hierarchy to develop optimal waste management at particular design and build stage level

(j) Build additional requirements into the design of the facility and the records management

(k) Set down research and development requirements to establish the gaps in knowledge that requires filling to achieve optimal waste management

(l) Interface with regulators and government to establish and inform all requirements set down

(m) Repeat a to l through concept, development, detailed design and build stages growing the database of information, future requirements of information and auditable trail of decisions

OPERATIONAL PHASE ASPECTS

Commence when radioactive materials are introduced into the plant.

(a) Review of government policies to establish how operational needs and experience are influenced by national expectations and fit into local as well as national strategic waste strategy

(b) Establish / upgrade waste management inventory with operational data

(c) Register and record all normal waste arisings as well as those outside the normal arisings

(d) Establish and monitor the behaviour of radioactive waste in the steps in the management of the radioactive materials and related radioactive wastes.

(e) Evolve the waste management inventory to incorporate all wastes identified

(f) Evolve via links established earlier waste disposal criteria, onward disposition criteria, storage criteria

(g) Improve and add detail to the Integrated waste strategy and plan and apply the waste management hierarchy to develop optimal waste management as information evolves from the facility

(h) Build additional requirements into the operation of the facility and the records management

(i) Develop the design and construction of the facility as it is modified during the operational phase to deal with where possible the gaps in knowledge that require filling to achieve optimal waste management

(j) Interface with regulators and government to establish and inform all requirements set down and interface with the national waste strategy and plan

(k) Repeat a to j through the commissioning, operation and shutdown phases growing the database of information, future requirements of information and auditable trail of decisions

DECOMMISSIONING PHASE ASPECTS

Commence when radioactive materials are removed from the plant.

(a) Review of government policies to establish national expectations and fit into national strategic waste strategy

(b) Establish / upgrade waste management inventory via techniques including monitoring

(c) Utilise the waste management inventory to establish the scope and condition of the waste remaining within the facility

(d) Establish and monitor the behaviour of radioactive waste in the steps in the management of the radioactive materials and related radioactive wastes by selection of appropriate methods and equipment that deliver optimal waste minimisation.

(e) Evolve the waste management inventory to incorporate all wastes identified

(f) Evolve via links established earlier waste disposal criteria, onward disposition criteria, storage criteria

(g) Improve and add detail to the Integrated waste strategy and plan and apply the waste management hierarchy to develop optimal waste management as information evolves from the facility

(h) Build additional requirements into the operation of the decommissioning process and the records management

(i) Interface with regulators and government to establish and inform all requirements set down and interface with the national waste strategy and plan

(j) Repeat a to i through the decommissioning and interim storage phases growing the database of information, future requirements of information and auditable trail of decisions

ANNEX 3. 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 in a repository;

(c) The diffusion of tritium under standard atmospheric conditions or conditions in a repository;

(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 buildup of evolved gases.

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