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SAFETY OF
NUCLEAR FUEL CYCLE FACILITIES

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SAFETY OF
NUCLEAR FUEL CYCLE FACILITIES

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FOREWORD
NOTE BY THE SECRETARIAT
THE IAEA SAFETY STANDARDS

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Requirements publication establishes requirements for all the important areas of safety in all phases of the lifetime of nuclear fuel cycle facilities, establishing requirements for both design and operation¹. It supersedes the Safety Requirements publication on Safety of Nuclear Fuel Cycle Facilities (IAEA Safety Standards Series No. NS-R-5) issued in 2008 and reissued (Rev. 1) with additional appendices in 2014.

1.2. Requirements for nuclear safety are intended to ensure the highest level of safety that can reasonably be achieved for the protection of workers and other personnel, the public and the environment from harmful effects of ionizing radiation arising from nuclear facilities, Ref. [1]. It is recognized that technology and scientific knowledge advance, and that nuclear safety and the adequacy of protection against radiation risks need to be considered in the context of the present state of knowledge. Safety requirements will change over time; this Safety Requirements publication reflects the present international consensus and the experience of Member States from using the previous edition.

1.3. Nuclear fuel cycle facilities are nuclear installations (other than nuclear reactors or critical experiments) where nuclear and radioactive materials are processed, handled, stored and prepared for disposal, in quantities or concentrations that pose potential hazards to workers, the public and the environment. The activities undertaken at these facilities include;

- (1) Processing and refining of uranium and thorium;
- (2) Conversion and enrichment of uranium;
- (3) Fabrication of nuclear fuels of all types;
- (4) Interim storage of fissile and fertile materials before and after irradiation;
- (5) Reprocessing of fuel and breeder materials from thermal and fast reactors;
- (6) Associated waste conditioning, effluent treatment and facilities for interim waste storage²;
- (7) Separation of nuclides from irradiated thorium and uranium;
- (8) Related research and development.

¹ Operation includes all activities performed to achieve the purpose for which an authorized nuclear fuel cycle facility was constructed. This includes maintenance, in-service inspection and other associated activities as well at the processing of radioactive material from introduction to exit from the facility.

² Interim waste storage provides functions for retrieval of the radioactive waste for later, permanent disposal.

Requirements for nuclear reactors, critical experiments, mining and milling facilities and waste disposal facilities are presented in other IAEA publications.

1.4. Nuclear fuel cycle facilities employ many diverse technologies and processes. Radioactive material is often processed through a series of interconnected units and consequently can be found throughout the entire facility. The physical and chemical forms of the processed material may also vary within a single facility. Some of the processes use hazardous chemical substances and gases, which may be toxic, corrosive, combustible, reactive³ or explosive and consequently may give rise to the need for specific requirements in addition to requirements for nuclear safety. A further feature specific to nuclear fuel cycle facilities is that they are often characterized by frequent changes in the mode of operation, in equipment and in processes. Operations at nuclear fuel cycle facilities generally require more operator intervention than those at nuclear reactors, which may result in specific hazards for the workers. On the other hand, the overall hazard to the public from many nuclear fuel cycle facilities can be low. The nature and diversity of the processes associated with the facilities result in a broad range of hazardous conditions and possible accidents that need to be considered and eliminated in the safety analysis. In view of the wide range of facilities and hazards, many requirements identified in this publication are to be applied using a graded approach⁴, Ref. [1].

OBJECTIVE

1.5. This publication provides a basis for safety and for safety assessment during all stages in the lifetime of nuclear fuel cycle facilities with particular emphasis on requirements for site evaluation, design, construction, commissioning, operation and preparation for decommissioning that must be satisfied to ensure safety. This publication also includes references to IAEA Generic Safety Requirements along with Specific Safety Requirements publications on aspects relating to regulatory supervision, management of safety, and site evaluation of fuel cycle facilities.

1.6. This publication is intended to be used by designers, operating organizations and regulatory bodies for ensuring the safety of nuclear fuel cycle facilities. These bodies should also be aware of the interfaces between safety and security highlighted in several parts of this publication. Particular emphasis is given to safety requirements for design and operation including commissioning. This publication must be used in conjunction with the associated IAEA Generic Safety Requirements and the safety guides, which provide recommendations on ways of meeting these requirements for specific facility types and activities.

³ Reactive chemicals give rise to exothermic reactions that may need control.

⁴ Graded approach: For a system of control, such as a regulatory system or a safety system, a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control. See Section 2 of this publication and Ref. [1] and [2].

SCOPE

1.7. This Safety Requirements publication applies to nuclear fuel cycle facilities of all types and sizes, including facilities for processing, refining, conversion, enrichment, fuel fabrication, storage and reprocessing of nuclear material and supporting ancillary facilities. The types of nuclear materials covered by these requirements include radioactive materials used as fissile or fertile fuels in thermal and fast reactors. In addition to processed uranium, these include plutonium, MOX fuel⁵, thorium breeder material and other types of experimental fuels including tritium. The ancillary facilities covered by these requirements include interim spent fuel storage and nuclear fuel cycle research and development facilities. Facility-specific requirements for the predisposal management of wastes and effluents containing radioactive and associated hazardous chemicals are also included. Facilities for mining and milling of ores are not within the scope of this publication.

1.8. This publication establishes requirements which help to meet the performance-based requirements of IAEA standards covering radiation protection in Ref. [2] and the pre-disposal of radioactive wastes in Ref. [3]. Where there is overlap or uncertainty regarding the application of this publication and other IAEA requirements and guidance, these standards can be regarded as complementary.

1.9. In view of the broad diversity of installations and operations covered, the requirements established in this publication are to be applied in a manner that is commensurate with the potential hazards for each facility by means of a graded approach. All the requirements established here are to be applied unless it can be justified that, for a specific facility, the application of certain requirements may be graded. For each such case the requirements to be graded are identified, taking account of the nature and possible magnitude of the hazards presented by the given facility and the activities conducted, see Section 2.

1.10. This publication does not address:

- (a) Requirements that are specifically covered in other IAEA Safety Requirements publications (e.g. Refs. [2, 4, 5, 6, 7]), except by grading their application;
- (b) Matters relating to nuclear security (other than the interfaces between nuclear safety and nuclear security, addressed in Section 11) or to the State system of accounting for, and control of, nuclear material;
- (c) Conventional industrial safety matters that under no circumstances could interfere with safe nuclear operation. For instance, a diesel spillage during a transfer of diesel generator fuel is not addressed unless it affects the nuclear safety of the facility but a HF release due to the escape and hydrolysis of uranium hexafluoride is.

⁵ MOX: Mixed uranium oxide (UO₂) and plutonium oxide (PuO₂).

1.11. IAEA safety requirements apply to all facilities and activities handling significant quantities of radioactive material where there are nuclear hazards. If a particular nuclear fuel cycle facility or activity involving radioactive material does not conform exactly to the scope of or description in IAEA safety standards, the IAEA requirements still apply as a basis for establishing specific requirements.

STRUCTURE

1.12. This Safety Requirements publication follows the relationship between the safety objective and safety principles, and between requirements for nuclear safety functions and design criteria and operational criteria for safety. It consists of eleven sections, one appendix and one annex. Section 2, draws on the Safety Fundamentals (Ref. [1]) and introduces the general safety objectives, concepts and principles for the safety of nuclear installations with emphasis on the radiation safety and nuclear safety aspects of nuclear fuel cycle facilities.

1.13. Sections 3 – 11 of this publication establish a number of overarching requirements that are numbered and highlighted in bold. Section 3 draws on Ref. [4] and deals with the general requirements on legal and regulatory infrastructure as far as these are relevant for nuclear fuel cycle facilities. Section 4 deals with requirements on topics relating to the management and verification of safety. This Section is based on the safety requirements publication on the Management System for Facilities and Activities (Ref. [5]). Section 5 establishes requirements regarding the selection of sites for new nuclear fuel cycle facilities and the evaluation of sites for all nuclear fuel cycle facilities. This Section is based on the safety requirements publication on Site Evaluation for Nuclear Installations (Ref. [6]). Section 6 establishes requirements for safety assessment for all plant states, the application of defence in depth and for the safe design of all types of nuclear fuel cycle facilities. Section 7 establishes one overarching requirement for construction of a nuclear fuel cycle facility. Section 8 establishes requirements for commissioning with a phased transition from inactive to active commissioning, when the requirements for full operation start to apply.

1.14. Section 9 establishes requirements for the safe operation of nuclear fuel cycle facilities, including maintenance, utilization and modification. It also covers the knowledge management that is applicable to other sections of this publication. Section 10 establishes requirements for the preparation of the safe decommissioning of nuclear fuel cycle facilities on the basis of Ref. [8], while Section 11 establishes requirements for the interface between safety and security. The appendix provides lists of postulated initiating events to be considered in the safety analysis for a nuclear fuel cycle facility. The Annex provides guidance on acceptability criteria for accidents. It does not provide definitive criteria as these are decided by Member States, whose nuclear programmes vary in scope and extent. Terms in this publication are to be understood as defined and explained in the IAEA Safety Glossary (Ref. [9]), unless otherwise stated (see “Note on Definitions”).

2. APPLYING SAFETY OBJECTIVES, CONCEPTS AND PRINCIPLES TO NUCLEAR FUEL CYCLE FACILITIES

GENERAL

2.1. The Fundamental Safety Principles (Ref. [1]) establish one fundamental safety objective and ten safety principles that provide the basis for requirements and measures to protect people and the environment from the harmful effects of ionizing radiation and for the safety of facilities and activities that give rise to radiation risks. Restricting the likelihood of events that might lead to a loss of control over a nuclear chain reaction or any other source of radiation also requires control over chemical and other non-nuclear hazards of nuclear fuel cycle facilities.

FUNDAMENTAL SAFETY OBJECTIVE

2.2. The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation. This fundamental safety objective has to be achieved, and the ten safety principles have to be applied, without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. To ensure that nuclear fuel cycle facilities are operated and activities are conducted so as to achieve the highest standards of safety that can reasonably be achieved, measures have to be taken to achieve the following (Ref. [1]):

- (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 the safety of the facility and its activities;
- (c) To mitigate the consequences of such events if they were to occur.

2.3. The fundamental safety objective applies for all facilities and activities in all plant states⁶ and for all stages over the lifetime of a facility or radiation source, including planning, siting, design, manufacturing, construction, commissioning and operation, as well as decommissioning and closure. This includes the associated transport of radioactive material and management of radioactive waste (Ref. [1]).

2.4. In the context of nuclear 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 need to be considered in the design, commissioning and operation of the facility. Activities at nuclear fuel cycle facilities may also include industrial processes that pose additional

⁶See note on definitions.

hazards to safe nuclear operations, site personnel and to the environment. Purely industrial hazards also need to be considered where these can interfere with safe nuclear operations.

FUNDAMENTAL SAFETY PRINCIPLES

2.5. The Fundamental Safety Principles (Ref. [1]) states that:

“Ten safety principles have been formulated, on the basis of which safety requirements are developed and safety measures are to be implemented in order to achieve the fundamental safety objective. The safety principles form a set that is applicable in its entirety; although in practice different principles may be more or less important in relation to particular circumstances, the appropriate application of all relevant principles is required.”

2.6. The requirements presented in this publication are derived from the fundamental safety objective of protecting people and the environment, and the related safety principles Ref. [1]:

Principle 1: Responsibility for safety

The prime responsibility for safety must rest with the person or organization⁷ responsible for facilities and activities that give rise to radiation risks.

Principle 2: Role of government

An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.

Principle 3: Leadership and management for safety

Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.

Principle 4: Justification of facilities and activities

Facilities and activities that give rise to radiation risks must yield an overall benefit.

Principle 5: Optimization of protection

Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

Principle 6: Limitation of risks to individuals

Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.

Principle 7: Protection of present and future generations

⁷For nuclear fuel cycle facilities this is the operating organization.

People and the environment, present and future, must be protected against radiation risks.

Principle 8: Prevention of accidents

All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.

Principle 9: Emergency preparedness and response

Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.

Principle 10: Protective actions to reduce existing or unregulated radiation risks

Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

The requirements derived from these principles must be applied to minimize and control the radiation risks to workers and site personnel, the public and the environment.

RADIATION PROTECTION

2.7. In order to satisfy the safety principles, it is required to ensure that for all operational states of a nuclear fuel cycle facility, doses from exposure to radiation within the installation or exposure due to radioactive discharges from the installation are kept within operational limits and below the dose limits and kept as low as reasonably achievable (optimization of protection and safety Ref. [2]).

2.8. To apply the safety principles, it is also required that nuclear fuel cycle facilities be designed and operated so as to keep all sources of radiation and nuclear material under strict technical and administrative controls⁸. However, these principles do not preclude limited exposures or the release of authorized amounts of radioactive substances to the environment from the facility in operational states. Such exposures and radioactive releases are required to be strictly controlled, to be measured or estimated, to be recorded and to be kept as low as reasonably achievable, in compliance with regulatory and operational limits as well as radiation protection requirements.

2.9. Although measures are taken to limit radiation exposure in all operational states to levels that are as low as reasonably achievable and to minimize the likelihood of an event that could lead to the loss of normal control over the source of radiation, there will remain a probability - albeit very low - that an accident could happen. Therefore, emergency arrangements are required to ensure that the consequences of any accident that do occur are mitigated. Such measures and arrangements include: engineered safety features; safety features for design extension conditions⁹, on-site emergency plans and procedures established by the operating organization; and where necessary in accordance with a

⁸ Administrative Control - Procedures, documented working practices or instructions that modify the actions of individuals and groups of workers for the purposes of maintaining or enhancing safety. The word safety is usually implied in the phrase "Administrative Control". Engineered controls that are more reliable than administrative controls are usually preferred.

⁹ See requirement 22 and note on definitions.

graded approach, off-site emergency response actions put in place by the appropriate authorities in accordance with Ref. [7].

2.10. The safety philosophy that is followed to fulfil the objective and principles stated in Ref. [1] relies on the defence in depth concept and on the adoption of measures for the management and verification of safety over the entire lifetime of the nuclear fuel cycle facility. In addition to automatic control many nuclear fuel cycle facilities rely on operator actions to maintain and control the safety of radioactive material throughout the facility. The safety philosophy addresses the means with which the organization supports individuals and groups to perform their tasks safely, taking the interactions between humans, technology and organizational aspects into account. The awareness by individuals of safety matters and the commitment of individuals to safety, and where appropriate the effective leadership and management of safety (Ref. [1]), are therefore essential to defence in depth.

CONCEPT OF DEFENCE IN DEPTH

2.11. The primary means of preventing accidents in a nuclear fuel cycle facility and mitigating the consequences of accidents if they do occur is the application of the concept of defence in depth (Ref. [1]: Principle 8). This concept is applied to all safety related activities, whether organizational, behavioural or design related, in all operational states. This is to ensure that all safety related activities are subject to independent layers of provisions, so that if a failure was to occur, it would be detected and compensated for or corrected by appropriate measures.

2.12. Application of the concept of defence in depth throughout design and operation provides protection against transients, anticipated operational occurrences and accidents, including those resulting from equipment failure or human action within the installation, and events induced by external hazards.

2.13. Section 3 of the Safety Fundamentals [1]) states that “Defence in depth is implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment. If one level of protection or barrier was to fail, the subsequent level or barrier would be available. The independent effectiveness of the different levels of defence is a necessary element of defence in depth”. The graded approach is applied to the concept of defence in depth in nuclear fuel cycle facilities. There are five levels of defence:

- (1) The purpose of the first level of defence is to prevent deviations from normal operation and the failure of items important to safety. This leads to requirements that the facility be soundly and conservatively sited, designed, constructed, maintained operated and modified in accordance with the management system and appropriate and proven engineering practices such as the application of redundancy, independence and diversity. To meet these objectives, careful attention is paid to the selection of appropriate design codes and materials, and to the quality control of the

manufacture of components and construction, of the facility. Design options, including process selection, that reduce the potential for internal hazards also contribute to the prevention of accidents at this level of defence. Attention is also paid to the processes and procedures involved in design, manufacture, construction and in-service inspection, maintenance and testing, to the ease of access for these activities, and to the way the facility is operated and to how operating experience is utilized. This process is supported by a detailed analysis that determines the requirements for operation and maintenance of the facility and the requirements for quality management for operational and maintenance practices;

- (2) The aim of the second level of defence is to detect and control deviations from normal operational states in order to prevent anticipated operational occurrences at the facility from escalating to accident conditions¹⁰. This is in recognition of the fact that postulated initiating events are likely to occur over the operating lifetime of a nuclear fuel cycle facility, despite the care taken to prevent them. This second level of defence necessitates the provision of specific systems and features in the design, the confirmation of their effectiveness through safety analysis, and the establishing of operating procedures to prevent such initiating events, or to minimize their consequences, and to return the plant to a safe state¹¹;
- (3) For the third level of defence, it is assumed that, although very unlikely, the escalation of certain anticipated operational occurrences or postulated initiating events might not be controlled at a preceding level of defence and a more serious event may develop. These unlikely events are anticipated in the design basis for the nuclear fuel cycle facility, and inherent safety features, fail-safe design, additional equipment and procedures are provided to control their consequences and to achieve stable and acceptable states of the facility following such events. This leads to the requirement that engineered safety features shall be capable of transferring the nuclear fuel cycle facility first to a controlled state and subsequently to a safe state, and maintaining at least one physical barrier¹² for the confinement of radioactive material. The radiological safety objective is to have no releases or radiation levels requiring off-site protective measures and returning the plant to a safe state.
- (4) The purpose of the fourth level of defence is to mitigate the consequences of accidents that result from failure of the third level of defence in depth. This is achieved by preventing the progression of the accident and mitigating the consequences of a severe accident¹³. The safety objective in the

¹⁰ See note on definitions.

¹¹ Facility state, following an anticipated operational occurrence or accident conditions, in which the main safety functions of the nuclear fuel cycle facility can be ensured and maintained stable for a long time.

¹² For most types and design of nuclear fuel cycle facilities a "physical barrier" is a combination of a "static" and a complementary "dynamic" (e.g. provided by a ventilation system) barrier that, together, provide effective containment/confinement.

¹³ A severe (nuclear fuel cycle) accident is any event affecting the facility resulting in off-site radiological consequences equal to or greater than the high contamination level or radiation level criteria for design extension conditions i.e. an event more severe than a design basis accident.

case of an accident with significant off-site consequences is that only protective measures that are limited in terms of times and areas of application would be necessary and that off-site contamination or high radiation levels would be avoided or minimized. Event sequences that would lead to early or large¹⁴ radioactive releases are required to be ‘practically eliminated’¹⁵.

- (5) The purpose of the fifth and final level of defence is to mitigate the radiological consequences of radioactive releases or radiation levels that could potentially result from accidents. This requires the provision of adequately equipped emergency response facilities and emergency plans and emergency procedures for on-site and off-site emergency response.

2.14. A relevant aspect of the implementation of defence in depth for a nuclear fuel cycle facility is the provision in the design of a series of physical barriers, as well as a combination of active, passive and inherent safety features that contribute to the effectiveness of the physical barriers in confining radioactive material at specified locations. The number of barriers that will be necessary will depend upon the initial source term in terms of amount and isotopic composition of radionuclides, the nature of any associated chemical hazard and the effectiveness of the individual barriers, the possible internal and external hazards, and the potential consequences of barrier failures. Similar considerations apply to the prevention of high radiation levels, particularly those arising from an uncontrolled criticality event, where external exposure of workers or the public is possible.

2.15. The defence in depth concept is applied mainly through the safety analysis and the use of sound engineering practices based on research and operational experience. This analysis is carried out in the design to ensure that the safety objectives are met. It includes a systematic, critical review of the ways in which the nuclear fuel cycle facility structures, systems and components¹⁶ could fail and identifies the consequences of such failures. The safety analysis examines:

- (1) All planned normal operational modes (including maintenance and shutdown) of the nuclear installation, and its performance during;
- (2) Anticipated operational occurrences;
- (3) Design basis accident conditions and, if necessary;
- (4) Event sequences that may lead to design extension conditions (Section 6 and Requirement 22)

¹⁴An early radioactive release is a release of radioactivity for which off-site protective measures are necessary but are unlikely to be fully effective in a timely manner. A large radioactive release is a release of radioactivity for which off-site protective measures limited in terms of times and areas of application are insufficient to protect people and the environment.

¹⁵ The possibility of certain conditions occurring is considered to have been practically eliminated (i.e. eliminated from further consideration) if it is physically impossible for the conditions to occur or if the conditions can be considered with a high level of confidence to be extremely unlikely to arise.

¹⁶See (Ref. [2]).

Requirements for the safety analysis in design are presented in Section 6 of this publication. These analyses are independently reviewed by the operating organization and by the regulatory body (see Section 3).

GRADED APPROACH

2.16. Nuclear fuel cycle facilities have diverse natures and types. Their design and operating characteristics may vary significantly and present a variety of different hazards. Application of a graded approach ensures that the extent to which control measures are applied to the safety of facilities are commensurate, to the extent possible, with the likelihood and possible consequences of a loss of control.

2.17. The attention given and level of detail involved in developing and approving the safety analysis and incorporating safety into the design of the facility and to ensuring the safety of the facility throughout its lifetime is required to be commensurate with the radiological and chemical hazards associated with the facility.

2.18. Where certain risks are demonstrated to be non-existent or very small, application of some features or procedures required for other higher risk/hazard facilities may be of less importance or unnecessary. In such situations, the graded approach can be used in applying certain requirements in this publication. No requirements can be waived. However, based on an appropriately approved assessment, the degree of application of certain requirements may be reduced, or in some cases effectively be “graded to zero” with an appropriate justification in the safety case. These requirements apply in full, without grading, to a small number of large nuclear fuel cycle facilities.

2.19. Requirements for the regulatory process and authorisations are presented in the next section. Requirements for the responsibilities of the operating organization are presented in Section 4.

3. REGULATORY SUPERVISION FOR NUCLEAR FUEL CYCLE FACILITIES

LEGISLATIVE AND REGULATORY INFRASTRUCTURE

3.1. According to the IAEA safety principles, the government is responsible for the adoption of legislation that assigns the prime responsibility for safety to the operating organization and establishes a regulatory body responsible for a system of authorization¹⁷, for the regulatory control of nuclear activities and for the enforcement of the regulations. These principles are established in (Principles 2 and 3 of Ref. [1]).

3.2. General requirements to fulfil these principles are established in “Governmental, Legal and Regulatory Framework for Safety” (Ref. [4]). This publication covers the essential aspects of the governmental and legal framework for establishing a regulatory body and for taking actions necessary to ensure the effective regulatory control of facilities and activities - existing and new - utilized for peaceful purposes. Other responsibilities and functions are also covered, such as liaison within the global safety regime and liaison for providing the necessary support services for the purposes of safety (including radiation protection), emergency preparedness and response, the interface with nuclear security¹⁸, and the State system of accounting for, and control of, nuclear material. These general requirements apply to the general legal and governmental infrastructure for the safety of nuclear fuel cycle facilities during site evaluation, design, construction, commissioning, operation, modification and preparation for decommissioning. A graded approach commensurate with the potential hazards of the facility shall be used in application of these requirements (Section 2: ‘Graded Approach’).

3.3. The State shall establish and maintain an independent body for the regulatory control of facilities and activities (Ref. [4]: Requirements 3, 4). To be effective, the regulatory body shall be provided with the statutory legal authority necessary to ensure that it can discharge its responsibilities and fulfil its functions. This includes the authority to review and assess safety related information submitted by the operating organization during the authorization process and to ensure compliance with the relevant regulations (e.g. by issuing, amending or revoking authorizations or their conditions), including carrying out compliance inspections and audits¹⁹, taking enforcement action and, providing other competent authorities or the public with information, as appropriate.

¹⁷ See (Refs. [2] and [4]: Requirement 23).

¹⁸ The IAEA issues guidance on nuclear security in the separate IAEA Nuclear Security Series of publications

¹⁹ Audits or surveillances etc. are independent assessments carried out to determine the extent to which the requirements for the management system are fulfilled, to evaluate the effectiveness of the management system and to identify opportunities for improvement. They can be conducted by or on behalf of the organization itself for internal purposes, by interested parties such as customers and regulators (or by other persons on their behalf), or by external, independent organizations

AUTHORIZATION PROCESS

3.4. Every project for a new nuclear fuel cycle facility shall follow an authorization process that comprehensively addresses all safety aspects, Ref. [4]. The authorization process is ongoing, starting at the site evaluation stage and continuing up to and including the decommissioning of the nuclear facility. The authorization process may vary among Member States but the major stages of the authorization process for nuclear fuel cycle facilities shall include:

- (1) Site evaluation;
- (2) Design;
- (3) Construction;
- (4) Commissioning;
- (5) Operation, including utilization and modification²⁰;
- (6) Shutdown;
- (7) Decommissioning;
- (8) Release from regulatory control.

3.5. In some cases, several stages may be authorized by a single licence, with conditions attached to control the subsequent stages. Despite these differences between national practices, a detailed demonstration of safety usually known as licensing documentation (or safety case)²¹ which includes an adequate safety analysis report shall be submitted by the operating organization to the regulatory body for review and assessment as part of the authorization process.

Requirement 1: Licensing documentation

The operating organization shall establish and justify the safety of its facility through a set of documents known as the licensing documentation (or ‘safety case’). The licensing documentation shall provide the basis for the safe siting, design, construction, commissioning, operation and decommissioning of the facility, including the justification for changes. The licensing documentation shall be considered in determining whether the authorizations necessary under national legislative requirements are to be granted, and thus it forms an important link between the operating organization and the regulatory body.

3.6. The licensing documentation shall include the safety analysis report and the operational limits and conditions, as well as any other information required by the regulatory body. The licensing documentation shall provide a detailed demonstration of the safety of the facility and forms the basis of all decisions relating to the safety of the facility that are made by the operating organization.

²⁰ Although the utilization (specification of material processed) and modification of nuclear fuel cycle facilities are activities that are normally included under operation, they may be considered separate stages in the authorization process since their safety implications give rise to a large amount of review and assessment activities that are repeated a number of times over the lifetime of the facility (see Requirement 5).

²¹ Any differences between the scope of the licensing documentation and the safety case (e.g. financial information, multiple approvals, and regulatory specifications) are outside of the scope of this publication. See (Ref. [2]) for definitions.

3.7. The safety analysis report shall describe all activities with safety significance in detail, including the limits on facility inputs and outputs (e.g. burn up and enrichment). It shall discuss the application of the safety principles and criteria in the design for the protection of operating personnel, the public and the environment. The safety analysis report shall contain an analysis of the hazards associated with the operation of the facility and shall demonstrate compliance with the regulatory requirements and criteria. It shall also contain safety analyses of accident sequences and of the safety features incorporated in the design for preventing accidents or minimizing the likelihood of their occurrence and for mitigating their consequences in accordance with the defence in depth concept.

3.8. The safety functions, associated safety limits and main items important to safety²² shall be identified in the safety analysis report, which shall also provide details of the emergency arrangements for the facility and details about the operating organization, the conduct of operations and the management system throughout the nuclear fuel cycle facility life.

3.9. The level of detail in the information to be presented by safety analysis report shall be determined using a graded approach. The safety analysis report shall cite additional references that may be necessary for a thorough review and assessment process. The referenced material shall be made readily available to the regulatory body. In all cases, the safety analysis report shall cover all of the topics identified above.

3.10. The licensing documentation shall define the required intervals for periodic testing and inspection of items important to safety. Consideration of the application of the principle of optimization of protection (Principle 5 of Ref. [1]) in the design and operation of the facility shall be included in the licensing documentation.

3.11. The operating organization shall submit the licensing documentation to the regulatory body in support of its application for authorization of the facility and periodically thereafter. A schedule for the submission of documents for review and assessment for the stages in the authorization process shall be agreed between the regulatory body and operating organization at an early date in a new nuclear fuel cycle facility project.

3.12. The regulatory body shall base subsequent authorization for stages in the lifetime²³ of the facility on relevant objectives, principles and associated criteria for safety to ensure that the facility presents no undue radiological risks to the personnel at the site, the public and the environment, and taking account of potential security threats. This review and assessment of the licensing documentation shall be carried out prior to authorization and repeated over the lifetime of the facility. The specific objectives of the regulatory review and assessment are provided in Ref. [4]. The review and

²²See (Ref. [2]).

²³ Authorisations may be required for siting, construction, commissioning, operation, modification (including change of use or site boundary alteration), shutdown, life-extension or decommissioning.

assessment by the regulatory body shall be commensurate with the potential magnitude of the hazard associated with the facility in accordance with a graded approach.

Acceptance criteria

3.13. States shall develop their own approach to acceptance criteria depending upon their particular legal and regulatory infrastructures. Acceptance criteria based on principles for safe design and operation shall be made available to the operating organizations, ideally before the project commences. The Annex to this publication provides one example of safety acceptance criteria, expressed in terms of the relationship between likelihood and consequence.

INSPECTION AND ENFORCEMENT

3.14. Paragraph 2.5 of Ref. [4] states that “an effective governmental, legal and regulatory framework for safety shall set out provision for the inspection of facilities and activities, and for the enforcement of regulations, in accordance with a graded approach”.

3.15. Paragraph 4.50 of Ref. [4] states that: “The regulatory body shall develop and implement a programme of inspection of facilities and activities, to confirm compliance with regulatory requirements and with any conditions specified in the authorization. In this programme, it shall specify the types of regulatory inspection (including scheduled inspections and unannounced inspections), and shall stipulate the frequency of inspections and the areas and programmes to be inspected, in accordance with a graded approach.”

3.16. Requirement 30 of Ref. [4] states that “The regulatory body shall establish and implement an enforcement policy within the legal framework for responding to non-compliance by authorized parties with regulatory requirements or with any conditions specified in the authorization”.

3.17. If there is evidence of a deterioration in the level of safety, or in the event of serious violations which in the judgement of the regulatory body could pose an imminent radiological, chemical or industrial hazard to the workers, the public or the environment, the regulatory body shall require the operating organization to curtail its activities and to take any further actions necessary to restore an adequate level of safety. In the event of continual, persistent or extremely serious non-compliance, the regulatory body shall direct the operating organization to curtail its activities and may suspend or revoke the authorization.

4. MANAGEMENT AND VERIFICATION OF SAFETY FOR A NUCLEAR FUEL CYCLE FACILITY

RESPONSIBILITY FOR SAFETY

Requirement 2: Responsibilities in the management of safety for a nuclear fuel cycle facility

The operating organization shall have the prime responsibility for the safety of the nuclear fuel cycle facility over its lifetime, from the beginning of the project for site evaluation, design, construction, through to commissioning, operation, utilization modification and decommissioning.

4.1. The operating organization and all other organizations engaged in activities important to the safety of a nuclear fuel cycle facility shall be responsible for ensuring that safety matters are given the highest priority.

4.2. In order to ensure rigour and thoroughness by all levels of the staff in achieving and maintaining safety, the operating organization shall:

- (a) Clearly define responsibilities and accountabilities with corresponding lines of authority and communication;
- (b) Ensure that it has sufficient qualified staff with appropriate experience at all levels for all activities that may affect safety;
- (c) Develop and strictly adhere to sound procedures for all activities that may affect safety, ensuring that managers and supervisors promote and support good safety practices while correcting poor safety practices;
- (d) Review, monitor and audit all safety related matters on a regular basis, implementing appropriate corrective actions where necessary;
- (e) Be committed to promoting and achieving a strong safety culture on the basis of a statement of safety policy and safety objectives which is prepared and disseminated and is understood by all staff;
- (f) Allocate adequate financial resources to ensure safety including provision for decommissioning.

4.3. Whenever a change of stage is to be initiated by the operating organization, it shall submit a detailed demonstration, which shall include an adequate safety analysis, for review and assessment by the regulatory body before the project is authorized to progress to the next stage. The safety analysis shall include an adequate demonstration of how the operating organization intends to discharge its responsibility for safety at all subsequent stages in the lifetime of the nuclear fuel cycle facility.

4.4. In a timely manner, the operating organization shall submit to the regulatory body any information that it requests. The operating organization shall be responsible for making arrangements with the designers and vendors to ensure the availability of any information that has been requested by the regulatory body. The operating organization shall also be responsible for informing the regulatory body of any new information on the nuclear fuel cycle facility and of any changes to information submitted previously. All information provided by the operating organization to the regulatory body shall be complete and accurate. The format and content of documents submitted to the regulatory body by the operating organization in support of the authorization shall be based on the requirements presented in this publication.

4.5. The regulatory body may request additional information, depending on the regulatory practices of the particular Member State. The functions and responsibilities of the operating organization for ensuring safety in each of the above phases and activities are presented in Section 3 (see Requirement 1) and here in Section 4 as well as in the relevant paragraphs of Sections 5 through 11 of this publication.

Requirement 3: Safety policy for a nuclear fuel cycle facility

The operating organization shall establish and implement safety, health and environmental policies that give safety the highest priority

4.6. The safety policy established and implemented by the operating organization shall give safety the utmost priority, overriding all demands including those of facility production and project schedules or research and development programmes. The safety policy shall promote a strong safety culture, including a questioning attitude and a commitment to excellent performance in all activities important to safety. Managers shall promote an attitude of safety consciousness among facility staff (Ref. [10]).

4.7. The safety policy shall stipulate clearly the leadership role of the highest level of management in safety matters. Senior management²⁴ shall be responsible for communicating and implementing the provisions of the safety policy throughout the organization. All personnel in the organization shall be made aware of the safety policy and of their responsibilities for ensuring safety. The expectations of the management for safety performance shall be clearly communicated to all personnel including external support organizations and contractors, and it shall be ensured that they are understood by all those involved in their implementation.

4.8. The safety policy of the operating organization shall include a commitment to achieving enhancements in operational safety. The strategy of the operating organization for enhancing safety and for finding more effective ways of applying and, where feasible, improving existing standards

²⁴‘Senior management’ means the person who, or group of people which, directs, controls and assesses an organization at the highest level (Ref. [2]). Many different terms are used, including, for example: chief executive officer, director general, executive team, executive board, plant manager, top manager, site vice-president, managing director and laboratory director.

shall be continuously monitored, periodically revised and supported by means of a clearly specified programme with clear objectives and targets.

4.9. To put these policies into effect the operating organization shall also specify and put in place organizational structures, standards and management arrangements. These organizational structures shall contain clear definitions of responsibilities, lines of authority and be capable of meeting the organization's objectives and public commitments under the safety policy.

INTEGRATED MANAGEMENT SYSTEM

Requirement 4: Integrated Management System

The operating organization shall establish, implement, assess and continuously improve an integrated management system for ensuring that all safety requirements are met in all phases of the lifetime of the nuclear fuel cycle facility.

4.10. The requirements for integrated management system²⁵ for facilities and activities are established in Ref. [5]. These requirements and the associated objectives and principles shall be taken into account in the development and implementation of the integrated management system for a facility by means of a graded approach on the basis of the importance to safety of each item, service or process. A graded approach shall be applied to determining the extent of the detailed integrated management system that is required for a particular nuclear fuel cycle facility.

4.11. The operating organization shall ensure through the establishment and use of an integrated management system that the nuclear fuel cycle facility is sited, designed, constructed, commissioned, operated and decommissioned, in a safe manner and within the operational limits and conditions that are established in the authorization.

4.12. The integrated management system shall be developed and established at a time consistent with the schedule for accomplishing phase related activities. In particular, activities for site investigation, which are usually initiated a long time before the establishment of a project, shall be covered by the integrated management system.

4.13. The integrated management system shall include all the elements of management so that structures, systems, and components, processes and activities important to safety are established and conducted coherently with other requirements, including those in respect of leadership, human

²⁵ An integrated management system is a single coherent management system in which all constituents of an organization are integrated to enable the organization's objectives to be achieved. Such constituents include the organizational structure, resources and organizational processes. This system integrates all elements of management including safety, health, environmental, security, quality and economic elements so that safety is not compromised

performance, security, quality, and protection of health and the environment. The integrated management system shall implement the safety policy.

4.14. The integrated management system shall identify and include the following requirements:

- The statutory and regulatory requirements of the Member State;
- Any requirements formally agreed with stakeholders;
- All the relevant IAEA Safety Requirements publications, including those established by this publication and those on emergency preparedness and response Ref. [7] and safety assessment Ref. [3].

4.15. The documentation of the integrated management system shall be reviewed and approved at appropriate levels of management in the operating organization and shall be submitted to the regulatory body for review and assessment as required.

4.16. The provisions of the integrated management system shall be based on four functional categories: management responsibility; resource management; process implementation and measurement, assessment, evaluation and improvement.

Management responsibility

4.17. Management responsibility includes planning, implementing and providing the means and support needed to achieve the organization's objectives. Management shall seek independent advice and regulatory agreement before major decisions affecting safety. In this regard, the integrated management system shall include provisions to ensure that processes and activities important to safety are carried out and controlled in a manner that ensures effective communication and clear assignment of responsibilities, in which accountabilities are unambiguously assigned to individuals, post-holders and suppliers.

Resource management

4.18. Resource management includes measures to ensure that the resources essential to the implementation of strategy and the achievement of the organization's objectives are identified and made available. The integrated management system shall require that:

- (a) The operating organization shall be resourced with competent managers and sufficient qualified personnel for the safe operation of the facility;
- (b) Suppliers, manufacturers and designers of items important to safety have an effective, integrated management system in place;
- (c) External personnel (including suppliers of both materials and services) are adequately trained and qualified and are performing their activities under the same controls and to the same standards as the facility personnel, and;

- (d) Equipment, tools, materials, hardware and software necessary to operate the facility at all stages of its lifetime in a safe manner are specified, supplied, checked, verified and maintained in accordance with the management system.

Process implementation

4.19. Process implementation includes the actions and tasks needed to achieve an appropriate level of quality, in accordance with a graded approach. These include identification of the processes of the integrated management system, and determination of the sequences in and interaction between those processes.

4.20. The integrated management system shall include provisions to ensure that the nuclear fuel cycle facility design, including subsequent changes, modifications or safety improvements, construction, commissioning, operational activities, and decommissioning are carried out in accordance with established codes, standards, specifications, procedures and administrative controls⁶. Means of detecting and correcting deficiencies in any of these activities shall be provided. Items and services important to safety shall be specified and controlled to ensure their proper use, maintenance and configuration. The use of computer codes for the justification of the safety of the facility, and their validation and verification (e.g. tests and experiments), shall be covered by the processes of the integrated management system.

4.21. During the manufacturing, installation and construction of items important to safety for the nuclear fuel cycle facility, processes shall be established to ensure that the relevant regulations and safety requirements are met and that the construction work is properly implemented. The processes shall allow the operating organization to ensure that the fabrication and construction of items important to safety are performed in accordance with the design intents and regulatory requirements.

4.22. As part of the integrated management system, procedures for the control of modifications shall be established, graded according to the safety significance of the modification. These processes shall cover the design, review, assessment and approval, fabrication, testing, and implementation of a modification project. Relevant procedures describing the processes shall be put into effect by the operating organization before the nuclear fuel cycle facility commissioning phase. For research and development the activities of the utilization programme (including new experiments) shall be subjected to the same requirements as those for modification projects on other types of nuclear fuel cycle facility.

4.23. Where a nuclear fuel cycle facility imports nuclear, toxic or flammable materials or generates products, waste or effluents, any safety implications of these materials and of any on-site transfer of these materials shall be covered by the processes of the integrated management system in accordance with a graded approach. The requirements for off-site transfer are given in Ref. [11].

4.24. The integrated management system shall ensure that items and services under procurement meet established design, quality and performance criteria. Suppliers shall be evaluated and selected on the basis of specified criteria which shall be periodically reviewed and suppliers re-evaluated. Requirements for reporting deviations from procurement specifications shall be specified in the procurement documents. Evidence that purchased items and services meet procurement specifications shall be made available for verification before the items are used or the services are provided.

Measurement, assessment, evaluation and improvement

4.25. Measurement, assessment, evaluation and improvement provide an indication of the effectiveness of management processes and work performance. The effectiveness of the integrated management system shall be periodically assessed (through audits²⁶). Weaknesses in processes and performance shall be identified and timely corrective action taken. The operating organization shall also evaluate the results of such audits and shall determine and implement the necessary actions for continuous improvements.

VERIFICATION OF SAFETY

Requirement 5: Safety assessment and periodic safety reviews for a nuclear fuel cycle facility

The adequacy of the design of the nuclear fuel cycle facility shall be verified by means of comprehensive safety assessment that includes a safety analysis report and defines any operational limits and conditions required for safety. The performance of the facility or activity in all plant states shall be assessed in the safety analysis and independently reviewed. On the basis of the results of the periodic safety review, the operating organization shall implement any necessary corrective actions and shall consider making justified modifications to enhance safety.

4.26. Requirements for the safety assessment for facilities and activities are established²⁷ in Ref. [12]. The adequacy of the nuclear fuel cycle facility design, including design tools and design inputs and outputs, shall be verified, validated and approved in a systematic process. The safety assessment process shall be undertaken by individuals or groups independent from those who originally carried out the design work. Verification, validation²⁸ and approval of the facility design shall be completed as early as is practicable in the design and construction processes, and in any case before commissioning of the facility is commenced. The management system shall include provision for ensuring the quality of the design of each structure, system and component, as well as of the overall design of the nuclear fuel cycle facility, at all times. This includes the means for identifying and correcting design deficiencies, for checking the adequacy of the design and for controlling design changes.

²⁶See footnote 17 for the definition of audits.

²⁷ This reference applies to all the paragraphs under this requirement.

²⁸In some quality systems, the term “validation” refers to the first test under active conditions. It is important that the verification that takes place before this stage is sufficiently rigorous to support decisions of safety significance.

4.27. The basis for the safety assessment in the design stage shall be the information derived from the safety analysis (see Section 6) as well as information from other sources such as research and operational experience. The safety assessment shall be part of the design process, with iterations made between the design activities and the confirmatory analytical activities and with increases in the scope and the level of detail of the safety assessment as the design progresses.

4.28. In accordance with the national regulatory requirements, the operating organization shall carry out systematic periodic safety reviews of the nuclear fuel cycle facility throughout its operational lifetime, with account taken of ageing, modifications, operating experience, technical developments, and new siting and other information relating to safety from other sources. The operating organization shall verify by analysis, surveillance, testing and inspection that the physical state of the facility is as described in the safety analysis report and other safety documents, including any approved modifications, and that the facility was commissioned and is operated in accordance with the safety analysis and operational limits and conditions.

4.29. The periodic safety review shall confirm that the safety analysis report and other documents (such as documentation for operational limits and conditions, maintenance and training) for the facility remain valid in view of current regulatory requirements; or, if necessary, to make improvements. In such reviews, changes in the site characteristics, changes in the utilization programme (particularly for research and development facilities), cumulative effects of ageing and modifications, changes to procedures, the use of feedback from operating experience and technical developments shall be considered and it needs to be verified that structures, systems and components and software important to safety comply with the design requirements.

4.30. The findings of safety assessments and periodic safety reviews shall be considered by the safety committee. The operating organization shall report to the regulatory body as required, in a timely manner, the confirmed findings of the periodic safety review that have implications for safety. Any modifications that arise from these findings shall be implemented in a timely manner.

Requirement 6: Safety committee for a nuclear fuel cycle facility

An independent safety committee (or an advisory group) shall be established to advise the operating organization facility manager on all safety aspects of the facility.

4.31. The operating organization shall establish one or more internal safety committees to advise the management of the operating organization on safety issues related to the commissioning, operation and modification of the facility. Such committees shall have among their membership the necessary breadth of knowledge and experience to provide appropriate advice. The committee shall be independent of the regulatory body and its membership shall, to the extent necessary, be independent of the operations management raising the safety matter.

4.32. The functions, authority, composition and terms of reference of the committee (or advisory group) shall be documented, based on graded approach and, if required, submitted to the regulatory body. The safety committee (or facility advisory group²⁹) shall be fully functioning before active commissioning of the facility commences and shall advise the operating organization facility manager³⁰ on:

- (i) Relevant aspects of the safety of the facility, and;
- (ii) The safety assessment of design, commissioning and operational issues.

4.33. The list of items that the safety committee is required to review shall also be established. Such a list shall include, as a minimum, the following items:

- (a) Proposed changes in the operational limits and conditions for the facility;
- (b) Proposed new tests, equipment, systems or procedures that have significance for safety;
- (c) Proposed modifications (temporary or permanent) to processes, equipment or systems that may have significance for safety;
- (d) Violations of the operational limits and conditions, of the licence and of procedures that are significant to safety;
- (e) Events that are required to be reported or that have been reported to the regulatory body;
- (f) Periodic reviews of the operational performance and safety performance of the facility;
- (g) Reports on routine releases of radioactive material to the environment;
- (h) Reports on radiation doses to the personnel at the facility and to the public;
- (i) The decommissioning plan;
- (j) Reports to be provided to the regulatory body;
- (k) Reports on regulatory inspections.

4.34. Before the safety committee is established the operating organization shall establish appropriate management systems to ensure relevant aspects of the facility design, changes to the design, operating procedures and safety assessment are subject to an appropriate level of review by the safety committee.

²⁹ In some Member States a different advisory group (or another safety committee) is established to advise the nuclear fuel cycle facility senior manager or senior management on the safety aspects of the day-to-day operation of the facility.

³⁰ The operating organization senior management has overall direct responsibility and authority for the safe operation of the nuclear fuel cycle facility, assigned by the operating organization and whose primary duties comprise the fulfilment of this responsibility. Some Member States may use differing titles for the equivalent role, such as facility manager, executive board etc.

4.35. Where the volume of work or a multiple facility site requires more than one safety committee, management systems shall be established to ensure that the committees' considerations and advice are complementary, consistent and coherent and that safety is not compromised.

5. SITE EVALUATION FOR NUCLEAR FUEL CYCLE FACILITIES

SITE EVALUATION

5.1. The main safety objective in evaluating the site for a nuclear fuel cycle facility is the protection of the public and the environment against the radiological and chemical consequences of normal and accidental releases of radioactive or other hazardous materials (for additional requirements see Ref. [6]). Information shall be collected in sufficient detail to support the safety analysis to demonstrate that the facility can be safely operated at the proposed site. The results of the site evaluation shall be documented and presented in sufficient detail to permit an independent assessment by the regulatory body.

5.2. In the evaluation of the suitability of a site for a nuclear fuel cycle facility, the following aspects shall be considered:

- (a) The effects of external events occurring in the region of the particular site (these events could be of natural origin or human induced);
- (b) The characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive releases;
- (c) The population density and population distribution and other characteristics of the external zone in so far as they may affect the possibility of implementing emergency response actions and the need to evaluate the risks to individuals and the population;
- (d) Potential nuclear security threats;
- (e) The presence of other nuclear or chemical facilities on or near the same site;
- (f) For facilities handling self-heating materials, the capability for an ultimate heat sink;
- (g) Other factors determined by the Government, which may include public acceptability.

5.3. If the evaluation of the site and the area of operations, including their foreseeable evolution, identifies deficiencies that cannot be compensated for by means of design features, site protection measures or administrative controls⁶, the site shall be deemed unsuitable. Design features and site protection measures are the preferred means of compensating for deficiencies.

5.4. The evaluation shall be graded so the amount of detail required for facilities where the unmitigated hazard is low (e.g. a natural uranium fuel fabrication facility) can be substantially reduced below that required for a medium or high risk facility (e.g. light water reactor fuel manufacture or a reprocessing facility). The site evaluation may constitute the first part of the development of the licensing documentation for a new facility. For the site evaluation, the following requirements apply:

- (a) Environmental characteristics of the area that may potentially be affected by the radiological impacts and the associated chemical impacts of the facility in all plant states shall be investigated. An appropriate monitoring system shall be designed to verify the predicted radiological impacts and associated chemical impacts.
- (b) The possible locations near the facility where radioactive material and other hazardous material could be discharged or could otherwise pass into the environment shall be investigated. Hydrological and hydrogeological investigations shall be carried out to assess, to the extent necessary, the dilution and dispersion characteristics of water bodies. The models used to evaluate the possible impacts of the contamination of surface water and groundwater on the public and the environment shall be described.
- (c) Models used to assess the dispersion of radioactive material and other hazardous material released to the environment in all plant states shall be in accordance with the requirements of the operating organization and of the regulatory body.
- (d) Information shall be collected which, together with the anticipated discharges of radioactive material and other hazardous material from the facility and with the transfer behaviour of the radioactive material, permits an assessment of doses to the public and of the contamination of biological systems and food chains.
- (e) In the analysis of the suitability of the site, consideration shall be given to the storage and transport of radioactive material, processing chemicals, radioactive waste and chemical wastes, and to the existing site infrastructure (e.g. the power supply and its reliability).

5.5. The site evaluation includes an analysis of the effect of normal operation of the facility on people and the environment around the site. If events of lesser severity but higher probability make a significant contribution to the overall risk, they shall also be considered in the design of the nuclear fuel cycle facility.

5.6. Hazards arising from external events (or from a combination of events), shall be considered in the design of the nuclear fuel cycle facility. Information and records, related to the occurrence and

severity of important natural phenomena shall be collected for the region³¹ in which the potential facility site is located and carefully analysed for reliability, accuracy and completeness. Combinations of external events, internal events and anticipated operational occurrences leading to large releases and early releases shall also be considered in the design.

5.7. The external events to be considered for evaluation include (Ref. [6]):

- (a) Earthquakes, volcanoes and surface faulting;
- (b) Meteorological events including extreme values of meteorological phenomena and rare events such as: lightning, tornadoes and tropical cyclones;
- (c) Flooding including water waves induced by earthquakes or other geological phenomena or floods and waves caused by failure of water control structures;
- (d) Geotechnical hazards including slope instability, collapse, subsidence or uplift of the site surface and soil liquefaction;
- (e) External human induced events (present and future) including transportation events such as aircraft crashes and accidents at surrounding activities such as chemical explosions.

5.8. The data generated by multiple applicants and licensees in the same region shall be combined, after any comparisons and quality checks have been completed.

5.9. In relation to the characteristics and distribution of the population, the combined effects of the site and the installation shall be such that:

- (a) For operational states of the facility the radiological exposure of the population remains as low as reasonably achievable and in any case is in compliance with national requirements, with account taken of international recommendations;
- (b) The radiological risk to the population associated with accident conditions, including those that could lead to emergency response actions being taken, is acceptably low.

5.10. During the site evaluation and before the start of construction of a nuclear fuel cycle facility, it shall be confirmed that there will be no insurmountable difficulties in the development of off-site emergency arrangements, where appropriate, prior to the start of nuclear fuel cycle facility operation (Refs. [6] and [7]).

5.11. When a new nuclear fuel cycle facility is planned, in or near to urban or suburban environment, the suitability of the site to accommodate a nuclear installation shall be carefully analysed to avoid unacceptable radiological risk to site personnel and public.

³¹ Some data will be specific to the precise location of the facility. Data used by multiple applicants and licensees in the same region shall be combined.

ONGOING SITE EVALUATION

5.12. The operating organization shall establish a programme of monitoring throughout the lifetime of the facility to evaluate natural and human-made changes in the area including demographics. Monitoring shall commence no later than the start of construction and continue through to decommissioning and licence termination. The operating organization shall review the monitoring results to compare them with the original predictions of possible changes to site characteristics.

5.13. Ongoing site monitoring and facility experience shall be re-evaluated periodically, typically every ten years. A re-evaluation after a shorter interval shall be considered in the event of evidence of potentially significant changes in hazards. If the re-evaluation identifies new information with regard to site characteristics, safety precautions, such as engineering controls and emergency preparedness, these shall be reviewed and modified as necessary. The site re-evaluation review may be combined with the periodic safety review.

6. DESIGN OF NUCLEAR FUEL CYCLE FACILITIES

DESIGN AND SAFETY ASSESSMENT

Requirement 7: Main safety functions

The design shall ensure the fulfilment of the following main safety functions for all plant states of the nuclear fuel cycle facility, the loss of which may lead to significant radiological or chemical consequences to the workers, the public or the environment:

- (a) Maintaining the sub-criticality of fissile material;**
- (b) Cooling and confining radioactive and associated harmful materials;**
- (c) Protecting people against external radiation.**

6.1. These main safety functions address the principles in Ref. [1] and specific requirements in Ref. [2]. By use of defence in depth, the facility shall be designed to operate normally in a manner that does not challenge these main safety functions. This is one of the principal means of avoiding cliff edge³² effects in nuclear fuel cycle facilities. Unless inherently safe³³, the systems that provide these functions are not intended as primary systems for normal control.

6.2. Confinement can depend on the cooling of some nuclear materials where a loss of cooling could eventually result in the dispersion of radioactive material. Confinement shall prevent any unplanned

³² See Note on Definitions

³³ Shielding and static confinement are often inherently safe systems capable of providing both normal and safety functions.

release of nuclear materials with radioactive or hazardous chemical properties. Planned releases of nuclear materials shall be controlled to within authorized limits and shall be as low as reasonably achievable. Any accidental releases shall be limited. Secondary safety functions associated with confinement include the integrity of items important to safety, removal of decay heat and prevention of the adverse consequences of radiolysis.

6.3. Sub-criticality shall be ensured for all facilities handling fissile materials above certain limits. However facilities which handle natural (unenriched) uranium and certain other materials, as defined by national regulations, shall be considered deterministically safe against a criticality accident³⁴.

6.4. A systematic approach shall be taken to identifying those items important to safety that are necessary to fulfil the main safety functions and defining the conditions and inherent features that contribute to or affect fulfilling, the main safety functions for all states of the facility.

6.5. Means of monitoring the status of the facility shall be provided for ensuring that the main safety functions are fulfilled for all states of the facility.

Requirement 8: Radiation protection for a nuclear fuel cycle facility

The design of a nuclear fuel cycle facility shall ensure that radiation doses to workers and other personnel at the facility and to members of the public do not exceed the dose limits, and that total doses are kept as low as reasonably achievable in operational states for the entire lifetime of the facility, and that they remain below acceptable limits and as low as reasonably achievable during, and following, accident conditions.

6.6. Acceptable limits for radiation protection associated with the relevant categories of all plant states shall be established, consistent with the regulatory requirements, for both internal and external exposure. Doses shall be optimized with use of dose constraints and reference levels, in accordance with Ref. [1].

6.7. The design shall ensure that facility states that could lead to high radiation doses or large radioactive releases are practically eliminated³⁵ and that there are no, or only minor, potential radiological consequences for facility states with a significant likelihood of occurrence.

Requirement 9: General design considerations for a nuclear fuel cycle facility

The design of a nuclear fuel cycle facility shall ensure that the facility and items important to safety have the appropriate characteristics to ensure that the safety functions can be performed with the necessary reliability, that the facility can be operated safely within the operational

³⁴ Such facilities typically handle trace quantities of fissile materials and in some states this process is called “exemption” from the criticality requirements and controls.

³⁵See footnote 13.

limits and conditions for its entire lifetime and can be safely decommissioned, and that impacts on the environment are minimized.

6.8. The design of a nuclear fuel cycle facility shall be such as to ensure that the requirements of the operating organization, the regulatory body and the requirements of relevant legislation, as well as applicable national and international codes and standards, are met. Due account shall be taken in the design of human capabilities and limitations and of factors that could influence human performance. Adequate information on the design shall be provided for ensuring the safe operation, utilization, maintenance and decommissioning of the nuclear fuel cycle facility, and to allow subsequent modifications and new operating regimes to be implemented.

6.9. The design shall take due account of the safety objectives in Section 2 and relevant available experience that has been gained in the design, construction and operation of other nuclear fuel cycle facilities, and of the results of relevant research and development programmes.

6.10. The design shall take due account of the results of deterministic safety analyses and as appropriate complementary probabilistic safety analyses to ensure that due consideration has been given to the prevention of accidents and to mitigation of the consequences of any accidents that do occur. The safety assessment shall be carried out during the design stage to ensure that safety and regulatory requirements can be met.

6.11. Hazards shall be considered in designing the layout of the facility and in determining the postulated initiating events and generated loadings for use in the design of relevant items important to safety.

6.12. The expected behaviour of the facility in any postulated initiating event shall be such that the following conditions can be achieved, in order of priority:

- (1) A postulated initiating event would produce no safety significant effects and would result in change towards a more safe and stable condition by means of inherent safety characteristics of the facility;
- (2) Following a postulated initiating event, the facility would be rendered safe by means of passive safety features or by the action of systems that are operating continuously in the state necessary to control the postulated initiating event;
- (3) Following a postulated initiating event, the facility would be rendered safe by the actuation of active items important to safety that need to be brought into operation in response to the postulated initiating event;
- (4) Following a postulated initiating event, the facility would be rendered safe by following specified procedures.

6.13. Where prompt and reliable action would be necessary in response to a postulated initiating event, provision shall be made in the design of automatic safety actions for the actuation of safety systems, to prevent progression to more severe facility conditions.

6.14. Where prompt action in response to a postulated initiating event would not be necessary, it is permissible for reliance to be placed on the manual initiation of systems or on other operator actions. For such cases, the time interval between detection of the postulated initiating event or accident and the required action shall be sufficiently long, and adequate administrative controls (such as operational and emergency procedures, see footnote 6) shall be specified to ensure the performance of such actions. An analysis shall be made of the potential for an operator to worsen an event sequence through erroneous operation of equipment or incorrect diagnosis of the necessary recovery process.

6.15. The operator actions necessary to diagnose the state of the nuclear fuel cycle facility following a postulated initiating event and to put it into a stable long term shutdown condition in a timely manner shall be facilitated by the provision in the design of adequate instrumentation to monitor the status of the nuclear fuel cycle facility, and adequate means for the manual operation of equipment.

6.16. The design shall ensure that the generation of radioactive waste and discharges to the environment are kept to the minimum practicable in terms of both activity and volume, and that wastes are categorized.

6.17. The designer shall arrange for the orderly and comprehensive provision of quality-assured design documentation to the operating organization.

Requirement 10: Application of the defence in depth concept for a nuclear fuel cycle facility
The design of a nuclear fuel cycle facility shall apply the defence in depth concept. The levels of defence in depth shall be independent as far as is practicable.

6.18. The defence in depth concept shall be applied to provide several levels of defence to prevent accidents that could lead to harmful effects on people and the environment, ensure that appropriate measures are taken and to mitigate the harmful consequences in the event that prevention fails (Refs. [1] and [13]). Defence in depth shall be implemented, taking the graded approach into account as described below and in Section 2.

6.19. The design shall take due account of the fact that the existence of multiple levels of defence is not a basis for continued operation in the absence of one level of defence. All levels of defence in depth shall be kept available at all times and any relaxations shall be justified for specific modes of operation including maintenance operations.

6.20. The design of the nuclear fuel cycle facility shall:

- (a) Provide successive verifiable barriers to the release of radioactive material and associated hazardous chemicals to the environment;
- (b) Use conservative margins, and the manufacturing and construction shall be of high quality so as to provide assurance that failures and deviations from normal operation are minimized and that accidents are prevented as far as is practicable, with adequate safety margins such that a small deviation in a plant parameter does not lead to a cliff edge effect³⁶;
- (c) Provide for the control of plant behaviour by means of inherent and engineered features, such that failures and deviations from normal operation requiring actuation of safety systems are minimized or excluded by design, to the extent possible;
- (d) Provide for supplementing the control of the plant by means of automatic actuation of safety systems, such that failures and deviations from normal operation that exceed the capability of control systems can be controlled with a high level of confidence, and the need for operator actions in the early phase of these failures or deviations from normal operation is minimized;
- (e) Provide for structures, systems and components and procedures to control the course of and, as far as practicable, to limit the consequences of failures and deviations from normal operation that exceed the capability of safety systems;
- (f) Provide multiple (diverse and independent, where possible) means for ensuring that each of the main safety functions is performed, thereby ensuring the effectiveness of the barriers³⁷ and mitigating the consequences of any failure or deviation from normal operation.

6.21. To ensure that the concept of defence in depth is maintained, the design shall prevent, as far as is practicable:

- (a) Challenges to the integrity of physical and procedural barriers;
- (b) Failure of one or more barriers;
- (c) Failure of a barrier as a consequence of the failure of another barrier and common-cause failures;
- (d) The possibility of harmful consequences of errors or omissions in operation and maintenance.

6.22. The design features, controls and arrangements necessary to implement the defence in depth concept shall be identified mainly by means of a deterministic analysis (which may be complemented by probabilistic studies) of the design and operational regime. The safety assessment shall be justified by the application of sound engineering practices, based on research and operational experience.

6.23. The design shall be such as to ensure as far as practicable, that the first, or at most the second, level of defence is capable of preventing an escalation to accident conditions for all failures or

³⁶See note on definitions.

³⁷“Barriers” in this context are the items important to safety and procedures which prevent an event progressing or provide mitigation against its effects (containment and confinement, static and dynamic “barriers”).

deviations from normal operation that are likely to occur over the operating lifetime of the nuclear fuel cycle facility.

6.24. Defence in depth shall be implemented by taking into account the graded approach as described in Section 2. The amount and type of radioactive material present, its potential for dispersion, the potential for nuclear, chemical or thermal reactions, and the kinetics of such events shall all be considered in determining the required number and strength of lines of defence.

6.25. The levels of defence in depth shall be independent to avoid a failure of one level reducing the effectiveness of other levels. In normal operation items or procedures important to safety shall not routinely be activated or challenged or only challenged by a very wide safety margin³⁸.

Requirement 11: Use of the graded approach for a nuclear fuel cycle facility

Use of the graded approach in application of the safety requirements for a nuclear fuel cycle facility shall be commensurate with the potential risk of the facility and shall be based on a safety analysis, engineering judgement and regulatory requirements.

6.26. The use of a graded approach in the application of the safety requirements shall not be considered as a means of waiving requirements and shall not result in compromising safety. Grading of requirements shall be justified and supported by safety analysis or engineering judgement.

6.27. The implementation of the safety requirements for any nuclear fuel cycle facility shall be commensurate with its potential hazards. The facility type and the following facility specific attributes shall be taken into account:

- (a) The nature and the physical and chemical forms of the radioactive materials that are used, processed and stored at the facility;
- (b) The scale of operations undertaken at the facility (i.e. the ‘throughput’ of the facility) and the inventory of hazardous material, including products and waste in storage;
- (c) The processes, technologies and hazardous chemicals that are associated with the radioactive material;
- (d) The available routes for the disposal of effluents and the storage of radioactive waste;
- (e) The proximity and scale of other hazards that could interfere with safe operations of the facility.
- (f) Siting, including external hazards associated with the site and proximity to population groups.

³⁸ Passive systems may be challenged where there is no “cliff edge” effect. For instance, shielding designed to reduce radiation to an acceptable level during an extreme event will also provide shielding during normal operations. However great care should be taken that, as far as practicable, any control system(s) are separate (diverse and independent) from the safety “trip system” e.g. the system that normally controls the level in a vessel and the ‘trip system’ designed to prevent the vessel overflowing due to an error or accident.

6.28. The personnel making grading judgements shall be suitably qualified and experienced. Great care is needed to avoid the loss of significant safety measures such as passive safety and features provided for defence in depth.

Requirement 12: Interfaces of safety with security and safeguards

Safety measures, nuclear security measures and arrangements for the State system of accounting for, and control of, nuclear material shall be designed and implemented in an integrated manner so that they do not compromise one another.

See also Section 11 on the Interfaces between safety and security in nuclear fuel cycle facilities and Ref. [2].

Requirement 13: Proven engineering practices for design

Items important to safety for a nuclear fuel cycle facility shall be designed in accordance with the relevant national and international codes and standards.

6.29. Items important to safety shall preferably be of a design that has previously been proven in equivalent applications³⁹. If not, items shall be of high quality and of a technology that has been qualified and tested.

6.30. National and international codes and standards that are used as engineering design rules for items important to safety shall be identified and evaluated to determine their applicability, adequacy and sufficiency, and shall be supplemented or modified as necessary to ensure that the quality of the design is commensurate with the associated safety function and consequences of failure.

6.31. Codes and standards applicable to items important to safety shall be identified and their use shall be in accordance with their classification (see Requirement 14). In particular, if different codes and standards are used for different types of items (e.g. for piping and for electrical systems), consistency between the codes and standards shall be demonstrated.

6.32. In case of items important to safety for which there are no appropriate established codes or standards, an approach derived from existing codes or standards for similar equipment having similar environmental and operational requirements shall be applied. In the absence of such codes and standards, the results of experience, tests, analysis or a combination of these shall be applied. The use of a results based approach shall be justified.

6.33. Where an unproven design or feature is introduced or where there is a departure from an established engineering practice, processes shall be defined under the integrated management system to ensure that safety is demonstrated by means of appropriate supporting research programmes,

³⁹This does not override the requirement to optimize safety by the use of new or improved designs and technology subject to appropriate qualification, testing and safety analysis.

performance tests with specific acceptance criteria or the examination of operating experience from other relevant applications⁴⁰. The new design feature or new practice shall be adequately tested to the extent practicable before being brought into service, and shall be monitored in service to verify that the behaviour of the nuclear fuel cycle facility is as expected.

6.34. Acceptance criteria shall be established for all plant states. For the design of items important to safety, acceptance criteria in the form of engineering design rules may be used. These rules may include requirements in relevant codes and standards established in the State or internationally. The acceptance criteria shall be provided to the regulatory body for review, Ref. [4].

6.35. Many nuclear fuel cycle facilities use aggressive chemicals under harsh environmental conditions, often involving thermal and mechanical cycling and the transfer of materials containing abrasive particulates and, in some cases, complex mixtures of elements and compounds unique to nuclear fuel cycle facilities. In establishing engineering design rules and acceptance criteria the effects of corrosion, erosion and similar processes shall be considered. These effects shall also be considered when establishing monitoring and inspection requirements and, where appropriate, management of facility ageing.

Requirement 14: Safety classification of items

All items important to safety for a nuclear fuel cycle facility shall be identified and shall be classified on the basis of their safety function and their safety significance.

6.36. The method for classifying⁴⁰ the safety significance of items important to safety shall be based primarily on deterministic methods complemented, where appropriate, by probabilistic methods (if available), with due account taken of factors such as:

- (a) The safety function(s) to be performed by the item;
- (b) The consequences of failure to perform a safety function;
- (c) The frequency with which the item will be called upon to perform a safety function;
- (d) The time following a postulated initiating event at which, or the period for which, the item will be called upon to perform a safety function.

6.37. The design shall be such as to ensure that any interference between items important to safety will be prevented, and in particular that any failure of items important to safety in a system in a lower safety class will not propagate to a system in a higher safety class or to items in other levels of defence in depth.

⁴⁰This classification reflects the significance for safety of the structures, systems and components. Its purpose is to establish a grading in the application of the requirements for design. There are other possible classifications or categorizations of structures, systems and components according to other aspects (e.g. seismic or environmental qualification, or quality categorization of structures, systems and components).

6.38. Equipment that performs multiple safety functions shall be classified in a safety class that is assigned to those functions having the highest safety significance.

6.39. Items and software for instrumentation and control that are important to safety shall be first identified and then classified according to their function and significance for safety. The basis of the safety classification of the structures, systems and components, including software, shall be stated and the design requirements shall be applied in accordance with their safety classification.

DESIGN BASIS

Requirement 15: Design basis for items important to safety

The design basis for items important to safety for a nuclear fuel cycle facility shall specify the necessary capability, reliability and functionality for the relevant operational states, for accident conditions and for conditions arising from internal and external hazards, to meet the specific acceptance criteria over the lifetime of the facility.

6.40. The design basis for each item important to safety shall be systematically justified and documented. The documentation shall provide all the necessary information for the operating organization to operate the nuclear fuel cycle facility and to maintain and, if necessary, eventually replace the item important to safety with a replacement or substitute item meeting the design intent and all functional requirements of the original item.

6.41. The challenges that the nuclear fuel cycle facility may be expected to face during its operational lifetime shall be taken into consideration in the design process. For example these challenges include all the foreseeable conditions and events relating to stages in the operational lifetime of the facility and to all plant states, site characteristics, design requirements and the limits of parameters and modes of operation.

Requirement 16: Identification of internal hazards

All foreseeable internal hazards for a nuclear fuel cycle facility shall be identified and all plant conditions that could directly or indirectly affect the safety of the nuclear fuel cycle facility shall be examined.

6.42. The goal of the safety assessment shall be to demonstrate that the risks to the workers and public from the radioactive materials and chemicals in the facility are acceptable in all plant states, when account is taken of the capabilities of the facility and the safety of operations.

6.43. All foreseeable hazards shall be examined systematically and in combinations with plant conditions⁴¹ and human activities, to identify all sources of potential radioactive or associated

⁴¹ Conditions include failures of items important to safety and human errors, or “faults”.

hazardous chemicals. Internal industrial hazards that could interfere with safe operation of the facility shall be identified. Internal and external hazards shall be identified that could affect multiple facilities on the same site.

6.44. All credible failures of safety function and human error that could result in a hazardous event shall be examined for all operating conditions of the facility, including shutdown. All non-radiological hazards, e.g. industrial and chemical hazards that may lead to radiological consequences shall be taken into account.

6.45. The potential for internal hazards such as fire, flooding, missile generation, pipe whip, jet impact, corrosion, erosion, vibration, thermal or pressure cycling or the release of fluid from failed systems or from other installations on the site shall be taken into account in the design of the facility, see Appendix. Appropriate preventive and mitigation measures shall be taken to ensure that nuclear safety is not compromised. Some external events could initiate also internal fires or floods or lead to the generation of missiles. Such interrelation or interaction of external events with internal hazards shall also be considered in the design where appropriate.

6.46. The resulting set of identified hazards shall be confirmed to be comprehensive and shall be defined in such a way that they cover credible failures of items important to the safety of the facility and human errors that could occur in any of the operating conditions of the facility.

Requirement 17: Identification of external hazards

All foreseeable external events for a nuclear fuel cycle facility, both individually and in credible combinations, shall be evaluated.

6.47. The design basis for natural and human induced external events shall be determined. The events to be considered shall include those that have been identified in the site evaluation, see Appendix.

6.48. Natural external hazards shall be addressed, including meteorological, hydrological, geological and seismic events, and all credible combinations thereof. Human induced external hazards arising from nearby industries and transport routes shall be addressed. In the short term, the safety of the facility shall not be dependent on the availability of off-site services such as electricity supply and firefighting services. The design shall take due account of site specific conditions to determine the maximum delay time by which off-site services need to be available.

6.49. The need for the nuclear fuel facility to be equipped with a seismic detection system shall be considered. Where necessary, in accordance with the safety analyses and the graded approach, in case of earthquakes exceeding specified thresholds, automatic process or facility shutdown systems shall be actuated, as necessary.

6.50. Features shall be provided to minimize any interactions between buildings containing items important to safety (including power cabling and instrumentation and control cabling) and any other structure as a result of external events considered in the design.

6.51. The design shall be such as to ensure that all items important to safety are capable of withstanding the effects of external hazards considered in the design, and if not, other features such as passive barriers shall be provided to protect the nuclear fuel cycle facility and to ensure that the main safety functions will be achieved.

6.52. The design shall provide for an adequate margin to protect items important to safety against levels of external hazards more severe than those selected for the design basis taking into account the site hazard evaluation.

Requirement 18: Design criteria and rules

Design criteria corresponding to all physical parameters shall be specified for each operational state of the facility and for each design basis accident or equivalent. Engineering design rules shall be applied to provide for safety margins such that no significant consequences would occur even if the operational limits were exceeded within these margins.

6.53. A comparison of event sequences (or their equivalent) shall be performed to identify the most challenging parameter values. The resulting limiting parameter values, with a reasonable margin, shall be used in the design of items important to safety, including experimental devices in R&D facilities.

6.54. The operating organization shall identify the criteria, codes and standards applicable to items important to safety and shall justify their use in all operational states, using a graded approach⁴². Typical areas covered by codes and standards include structural, mechanical and electrical design, criticality safety and fire protection. In particular, if different criteria, codes and standards are used for different aspects of the same item or system, consistency between them shall be demonstrated. The regulator shall approve the selection of design codes when necessary.

6.55. The operating organization shall specify recognised engineering design rules for the design, to provide safety margins and avoid cliff edges with effects over and above those foreseen from anticipated operational occurrences.

Requirement 19: Specification of operational limits and conditions

Operational limits and conditions shall be prepared during the design phase, confirmed during the commissioning phase and established before operations of the facility commence.

⁴² For instance, the designer may not design to the Class 1 section of the design code where Class 3 would fulfil the required safety objective. The designer also has some discretion in estimating loads for the classification of structures and components, and hence in the selection of codes.

6.56. The operational limits and conditions are the set of rules that establish parameter limits, the functional capability and the performance levels of equipment and personnel for the safe operation of a facility. Any operational limits and conditions necessary for safe operation shall be developed during the design phase for a new facility and updated, if necessary, during commissioning to allow time for validation and approval.

6.57. The safety analysis report shall describe the assumptions and provide the basis for the operational limits and conditions presented in the licensing documentation.

ACCIDENT ANALYSIS

Requirement 20: Identification of postulated initiating events

Postulated initiating events, including human-induced events that could affect safety shall be identified and their effects, both individually and in credible combinations, shall be evaluated.

6.58. The list of hazards generated from Requirements 16 and 17 shall be used to select initiating events for detailed further analysis⁴³. Postulated initiating events shall be identified on the basis of engineering judgement, operational experience feedback and deterministic assessment, complemented by probabilistic methods where appropriate. The resulting set of identified postulated initiating events shall be confirmed to be comprehensive.

6.59. Certain events might be consequences of other events, such as a flood following an earthquake, or a large external event, such as an earthquake causing multiple simultaneous events on a facility site or several fires and major releases of hazardous materials⁴⁴ from various source locations. Credible consequential effects shall be considered to be part of the initiating event. The safety analysis shall demonstrate the ability of the design to withstand combinations of abnormal operating occurrences.

6.60. The postulated initiating events used for developing the performance requirements for the items important to safety in the overall safety assessment and the detailed analysis of the nuclear fuel cycle facility shall be grouped into representative event sequences that identify bounding cases and that provide the basis for the design and the operational limits for items important to safety.

6.61. An analysis of the postulated initiating events shall be made to establish the preventive and protective measures that are necessary to ensure that the required safety functions will be performed.

⁴³ Including the types of human-induced hazard described under Requirement 17.

⁴⁴ Chemical, explosive or other properties associated with radioactive material could be hazardous, and hazardous properties of non-radioactive materials could also threaten safe nuclear operations at the facility.

6.62. A technically supported justification shall be provided for exclusion from the design of any initiating event that is identified in accordance with the comprehensive set of postulated initiating events.

Requirement 21: Design basis accidents

A comprehensive safety analysis shall be carried out during the design process for a nuclear fuel cycle facility. Systematic and recognised methods of deterministic analysis shall be used, complemented by probabilistic assessments where appropriate, with use of a graded approach. The purpose of the analysis shall be to ensure that the design provides an adequate level of safety and meets required design acceptance criteria.

6.63. The safety analysis and the design are interactive and iterative processes undertaken to assure an adequate level of safety. The analysis shall cover the safety of all operational states (including normal radiological exposures) and accidents (Ref. [12]). For each design basis accident, the consequences to personnel, the public and the environment shall be estimated. Non-radiological consequences of nuclear operations shall be included in the analysis, along with the potential effect of new facilities on existing nuclear activities nearby.

6.64. As part of the accident analysis, event scenarios or groups⁴⁵ of event scenarios shall be identified and design basis accidents⁴⁶ or equivalent shall be postulated. The analysis shall confirm that the possible consequences of design basis accidents are acceptable and that the likelihood of accident has been appropriately minimized. The potential for multiple accident scenarios developing simultaneously from a single initiating event shall be considered.

6.65. For each accident scenario, the safety functions and corresponding items important to safety and administrative controls⁶ that are used to implement the defence in depth concept shall be identified. Mobile equipment that is important to safety shall be included in the analysis. The safety analysis shall provide assurance that uncertainties have been given adequate consideration in the design and especially that adequate margins are available to avoid cliff edge effects and large or early radioactive releases.

6.66. The following hierarchy of design measures shall be used for protection against potential hazards:

- (1) Process selection to eliminate inherent hazards;
- (2) Passive design controls;
- (3) Active design controls;
- (4) Administrative controls

⁴⁵Event scenarios may be grouped by event and hazard type (e.g. loss of confinement, criticality, fire, etc.).

⁴⁶See note on definitions.

6.67. Within these requirements and the general framework of Section 2, the operating organization shall specify explicit acceptance criteria for the level of safety to be achieved. Limits shall be set on the radiological consequences and associated chemical consequences for the workers and the public, from direct and indirect exposures to radiation, authorized radioactive discharges and related industrial hazards in all plant states. The limits shall be set equal to, or below, the levels set in national regulations, regulatory guidance, international and national standards to ensure compliance across the full range of facility conditions and throughputs. For new facilities, targets⁴⁷ shall be considered that are below these limits, since it is generally more effective to incorporate enhanced safety provisions at the design stage.

6.68. In setting limits related to accident conditions in the design basis, the risks from adverse events shall be characterized as tolerable risks or unacceptable risks such that the acceptability of consequences for the public and the workers is linked to the frequency or probability of occurrence. Such limits may be represented in the form of an acceptability diagram, with lower levels of consequence for events with higher frequencies, see the **Annex**. Additional provisions can be made in accordance with the defence in depth principle.

6.69. The design and the analysis shall be iterated until adequate levels of safety have been attained by the design according to the specified acceptance criteria, using a graded approach.

6.70. The principal conclusions of the analysis shall include the safety limits for items and activities important to safety and any operating rules and conditions necessary. The preparation of operating procedures and plans for radiological protection, criticality prevention, industrial safety and for emergency preparedness and response shall be based on the results of the analysis.

Requirement 22: Design extension conditions

A set of design extension conditions shall be derived on the basis of deterministic analysis and engineering judgement using a graded approach with complementary probabilistic assessments (as appropriate) to further improve the safety of the nuclear fuel cycle facility by enhancing its capabilities to withstand, without unacceptable consequences, accidents that are either more severe than design basis accidents or that involve additional failures.

The design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences.

6.71. An analysis of design extension conditions shall be performed. The main technical objective of considering the design extension conditions shall be to provide assurance that the design of the facility

⁴⁷Some States use the term 'constraints'.

is such as to prevent accident conditions not considered design basis accident conditions, or to mitigate their consequences, as far as is reasonably achievable. For facilities where Design Extension Conditions have been identified by the analysis, additional safety features or extension of the capability of safety systems to prevent or mitigate the consequences of a severe accident¹¹ shall be provided.

6.72. The design extension conditions shall be used to specify safety features and in the design of all other items important to safety that are necessary for preventing the occurrence of accidents more severe than the design basis, or, if they do occur, for controlling them and mitigating their consequences. For existing nuclear fuel cycle facilities, a complementary safety reassessment shall be performed to determine the need for implementing mitigating measures or modifications of the facility.

6.73. The facility shall be designed such that the possibility of conditions arising that could lead to early releases, or to large releases¹², is practically eliminated¹³. The design shall be such that for design extension conditions, protective actions that are limited in terms of times and areas of application shall be sufficient for the protection of the public, and sufficient time shall be available to take such measures. In specifying such protective measures, the postulated initiating events that lead to design extension conditions shall also be analysed for their capability to compromise the ability to provide emergency protective measures. Only those protective measures that can be reliably initiated within sufficient time at the location shall be considered available.

6.74. The analysis undertaken shall include identification of the features that are designed for use in, or that are capable of preventing or mitigating, events considered in the design extension conditions. These features:

- (a) Shall be independent, to the extent practicable, of those used in more frequent accidents;
- (b) Shall be capable of performing in the environmental conditions pertaining to design extension conditions, as appropriate;
- (c) Shall be reliable commensurate with the function that they are required to fulfil.

Combinations of events and failures

6.75. Where the results of engineering judgement and deterministic safety analyses complemented by probabilistic safety assessments (if available) indicate that combinations of events could lead to combined abnormal operating occurrences and accident conditions, such combinations of events shall be considered to be design basis accidents or shall be included as part of design extension conditions, depending mainly on their likelihood of occurrence. Certain events might be consequences of other events, such as a flood following an earthquake, or multiple events may be initiated within the facility from one external event, such as several leaks. Such consequential effects shall be considered to be part of the original postulated initiating event.

Requirement 23: Analysis of fires and explosion

The potential for external and internal fires and explosion shall be analyzed and potential initiating events shall be identified for the safety analysis. Specific controls required for fire and explosions shall be identified clearly.

6.76. A fire hazard analysis and an explosion hazard analysis shall be carried out for the nuclear fuel cycle facility to determine the necessary ratings of fire barriers and identify means of passive protection and appropriate physical separation against fires and explosions. Fires and explosions originating externally to the site and within the site shall be considered using a graded approach. The analysis shall cover all means of fire prevention and control:

- (a) Fire prevention;
- (b) Fire detection;
- (c) Fire extinction;
- (d) Segregation and barriers to prevent the spread of fire and smoke;
- (e) Escape of personnel.

6.77. The fire and explosion hazard analyses shall consider both fires involving nuclear material and fires affecting nuclear material explicitly. The analyses shall demonstrate that a single event cannot prevent a safe shutdown or result in an uncontrolled release of radioactive material from the facility. The analyses shall identify:

- Potential initiating events for use in the safety analysis;
- The potential for common cause failure caused by fires or explosions;
- Appropriate limits on flammable materials in process areas, switch rooms and control rooms.

6.78. Where appropriate, the analysis shall demonstrate that firefighting systems would not increase the criticality risk, would not harm operating personnel, would not significantly impair the capability of items important to safety, and would not simultaneously affect redundant safety groups and thereby render ineffective the measures taken to comply with the single failure criterion. Rupture and spurious or inadvertent operation shall be covered in the analysis, applying the graded approach.

SPECIFIC REQUIREMENTS FOR DESIGN

Requirement 24: Design for items important to safety

The design of a nuclear fuel cycle facility shall ensure that the facility and items important to safety have the appropriate characteristics to ensure that the safety functions can be performed with the necessary reliability, that the facility can be operated safely within the operational limits and conditions for its entire lifetime and can be safely decommissioned, and that impacts on the environment are minimized.

6.79. The safety assessment shall identify those items, including buildings, whose failure due to internal or external events could compromise the main safety functions, and their failure shall be prevented by design. Items important to safety shall be designed and located with due consideration to other implications for safety, to withstand the effects of hazards or to be protected, according to their importance to safety, against hazards and against common cause failure mechanisms generated by hazards.

6.80. The items (including buildings) important to safety shall be designed for all operational states, design basis accidents and, as far as practicable for design extension conditions. The design shall take account of the human and organizational factors identified under Requirement 29.

6.81. Items important to safety shall be designed to withstand the effects of extreme loadings and environmental conditions (e.g. extremes of temperature, humidity, pressure, radiation levels) arising in operational states and in relevant design basis accident (or equivalent) conditions⁴⁸.

6.82. The design for process control shall incorporate provisions for bringing abnormal operating conditions to a safe and stable state. If an emergency shutdown of the facility or part(s) thereof is necessary, the interdependences between different processes shall be considered.

6.83. In anticipated operational occurrences and in accident conditions, it may be necessary for the operator to take further action to place the facility in a safe and stable long term state. Manual operator actions shall be analysed appropriately and shall be sufficiently reliable to bring the process to a safe state provided that:

- (a) Adequate time is available for the operator to take actions for safety;
- (b) The information available has been suitably processed and presented;
- (c) The diagnosis is simple and the necessary action is clearly specified;
- (d) The demands imposed on the operator are not excessive.

6.84. If any of the above conditions may not be met, the safety systems shall be such as to ensure that the facility attains a safe state.

6.85. Where prompt, reliable action would be required in response to postulated initiating events, the design of the facility shall include the means to actuate automatically the necessary safety systems.

⁴⁸ Effects of extreme loadings include:

- (1) Distortion of items with 'geometrically favourable' dimensions;
- (2) Rainwater ingress to building handling nuclear material;
- (3) Weathervaning of tower crane used to lift nuclear material or waste;
- (4) The effect of pressure surges on HEPA filters, caused by escaping gases;
- (5) Zero readings from saturated instruments such as radiation detectors in a high field.

6.86. A capability shall be provided for monitoring all essential processes and equipment during and following anticipated operating occurrences and accidents. If necessary, a remote monitoring and safe shutdown capability shall be provided.

6.87. Within the design of the facility, consideration shall be given to further increasing shielding designed to address external exposure, where practical, in order to reduce the consequences of a criticality accident. The design and layout of shielding shall take account of its potential for degradation.

6.88. Strengthening of the structure shall be considered to withstand or mitigate the effects of accident conditions such as explosion or criticality.

6.89. Items important to safety either shall be capable of functioning after loss of support systems, e.g. compressed air, or shall be designed to fail to a safe configuration, with acceptable positions, settings and signals (or indicating their failed status clearly).

6.90. The design organization shall ensure that the knowledge of the design and its configuration that are needed for safe operation, maintenance (including adequate intervals for testing) and modification is available.

Requirement 25: Redundancy, diversity, independence and separation

As required by the safety analysis, the design shall make adequate provision for redundancy, diversity, independence and physical separation of equipment.

6.91. The facility shall be designed so that a single fault or equipment failure cannot lead to accidents exceeding the conditions of the design basis. Adequate redundancy, diversity and independence with physical separation shall be provided for items important to safety.

6.92. The principles of redundancy and independence shall be applied as important design principles for improving the reliability of functions important to safety. The design shall be such as to ensure that no single failure could result in a loss of the capability of a system to perform as intended.

6.93. The principles of segregation and diversity shall be considered in the design of the facility to enhance reliability of items important to safety and to reduce the potential for common cause failures.

Requirement 26: Features to facilitate radioactive waste management

The incorporation of features to facilitate radioactive waste management at the nuclear fuel cycle facility shall be considered at the design stage. Generation of radioactive waste shall be kept to the minimum practicable in terms of both activity and volume, by means of appropriate design measures. The predisposal and disposal routes for waste shall be considered with the same aim of minimizing the overall environmental impacts.

6.94. The design of the facility shall incorporate appropriate features to facilitate radioactive waste management. Waste processing and storage shall be provided in accordance with pre-established criteria and the national waste strategy, and shall take into consideration both on-site storage capacity and disposal options.

6.95. The design of the facility shall enable safe management of radioactive waste and effluents arising from operational states, maintenance and periodic clean-out of the facility. Due consideration shall be given to the various natures, compositions and activity levels of the waste generated in the facility.

6.96. The design shall take due account of:

- (a) The choice of materials and, where applicable, surface finishes, so that amounts of radioactive waste will be minimized to the extent practicable and decontamination will be facilitated;
- (b) The access capabilities and the means of handling, including lifting requirements, that might be necessary;
- (c) The facilities necessary for the processing (i.e. pre-treatment, treatment and conditioning) and storage of radioactive waste generated during operation and provision for managing the radioactive waste that will be generated in the decommissioning of the facility.

6.97. The design of facilities shall endeavour, as far as practicable, to ensure that all wastes anticipated to be produced during the life cycle of the facility have designated disposal routes. Where these routes do not exist at the design stage of the facility, provisions shall be made to facilitate envisioned future options.

6.98. Waste processing and where necessary interim storage facilities shall be considered within the scope of the overall facility design. The requirements on the generation, processing and storage of radioactive waste established in Ref. [3] shall be applied.

6.99. Systems and facilities shall be provided for the safe management of radioactive waste on the nuclear fuel cycle facility site to enable radioactive waste characterization, segregation, encapsulation, and interim storage that cover the current and future inventory of radioactive waste. These facilities are themselves nuclear fuel cycle facilities to which this requirements publication applies in a graded manner.

6.100. Nuclear materials that generate heat shall be stored in facilities that maintain a suitably reliable heat removal function in addition to adequate confinement and shielding.

6.101. This requirement shall also be considered in the design of any modifications to the facility or any new utilization of a nuclear fuel cycle R&D facility.

Requirement 27: Design for the management of atmospheric and liquid radioactive discharges

Design provisions shall be established for ensuring that discharges of gaseous, liquid and particulate radioactive materials and associated hazardous chemicals to the environment comply with authorized limits and to reduce doses to the public and effects on the environment to levels that are as low as reasonably achievable.

6.102. Nuclear fuel cycle facilities shall be designed to minimise the impact of radioactive and toxic effluents from normal operations on the public and the environment. Management of radioactive effluents including discharge shall follow requirements established in Refs. [2] and [3]. The designer shall consider the whole site when applying these requirements, applying a graded approach to the optimization of protection in accordance with Ref. [1].

6.103. Systems shall be provided for the treatment of gaseous and liquid radioactive effluents to keep their volumes and the amount of radioactivity below the authorized limits for discharges and as low as reasonably achievable. These provisions shall account for any hazardous chemicals and particulate matter that is present or potentially present.

6.104. The safety and environmental assessment shall consider the need for monitoring, collecting potentially contaminated effluents and appropriately treating (e.g. filtering) them prior to discharge to the environment. Design features shall be provided to ensure discharges are within authorized limits prior to their release to the environment by authorized means.

6.105. Where radioactive or toxic material may leak or bypass a filter, the design shall accommodate the testing (in accordance with accepted international standards) of removal efficiencies for final stages of cleaning (filters, scrubbers or beds) to ensure that they correspond to the removal efficiency used in the design.

6.106. The safety assessment shall determine the need for real time measurements to confirm that cleaning systems are working effectively and the continuous measurement of discharges. Design provisions shall be established for monitoring aerial and liquid radioactive discharges to the environment.

Requirement 28: Design for maintenance, periodic testing and inspection of items important to safety

Items important to safety shall be designed to facilitate maintenance, inspection and testing for their functional capability over the lifetime of the facility.

6.107. The design and layout of items important to safety shall include provision to minimize exposures arising from maintenance, inspection and testing activities. The term maintenance includes both preventive and corrective actions.

6.108. Specific attention shall be paid to design for maintenance of equipment⁴⁹:

- That is installed in high-active areas such as hot cells;
- To be used in facilities with a long design lifetime.

Requirement 29: Ergonomics and human factors

Human factors and human–machine interfaces shall be considered throughout the design process.

6.109. The design process shall give due consideration to the layout of facilities and equipment, and to procedures, including procedures for maintenance and inspection, facilitating interaction between the operating personnel and the facility in all process states.

6.110. Human factors and ergonomic principles shall be applied in the design of remote-handling and glove-boxes, control rooms and panels, with consideration of the situational awareness⁵⁰ of operators. Control panels shall be provided with clear displays and audible signals for those parameters that are important to safety.

6.111. The design shall minimize the demands on operators in normal operations, in anticipated operational occurrences and in accident conditions, by considering provision of the following;

- (1) Automating appropriate actions to promote the success of the operation;
- (2) Providing clear indications whenever significant changes of process state occur;
- (3) Appropriate interlocks, keys, passwords and other control devices;
- (4) Barriers preventing accidental contact between operators and hazardous materials.

6.112. Staff undertaking analyses of human and organizational factors shall be appropriately trained and qualified. Operating personnel who have gained operating experience in similar facilities shall, as far as is practicable, be actively involved in the design process, in order to ensure that consideration is given to the future operation (including abnormal and accident conditions) and maintenance of equipment.

Requirement 30: Direction and delivery of nuclear and associated hazardous materials

The direction and delivery of materials shall be considered in the safety analysis and the severity of any errors determined. The design shall provide features to ensure the correct delivery of nuclear materials and chemicals.

⁴⁹ See also Requirements 34 and 47.

⁵⁰ Situational awareness refers to the holistic assessment of workload, layout, communications, operator support tools etc.

6.113. The control over transfers of hazardous⁵¹, radioactive and fissile materials between areas and buildings shall be addressed in the safety analysis. Provisions shall be made for operators to specify the destination of material accurately, detect misdirected material and reject incoming materials that do not meet acceptance criteria. Particular care shall be taken for controls on potential routing to effluent streams or the environment and the transfer of materials from within containment or shielding to areas of lower levels of containment or shielding.

6.114. Packages containing fissile materials subject to criticality controls shall be clearly labelled. Appropriate instrumentation and control (I&C), isolation and sampling shall be provided, in accordance with a graded approach.

Requirement 31: Design considerations for ageing management

In the design stage, design safety margins shall be adopted so as to accommodate the anticipated properties of materials at the end of their design life.

6.115. The design and layout of items important to safety including containment systems and neutron absorbers shall take account of the potential for age-related degradation of materials.

6.116. Where details of the characteristics of materials whose mechanical properties may change in service are unavailable, a system of monitoring shall be developed in the design to minimize the risks brought about by the effects of ageing, process chemistry, erosion, corrosion and irradiation on materials, see Requirements 28 and 63.

PROVISIONS FOR PLANT STATES

Requirement 32: Design for emergency preparedness

The nuclear fuel cycle facility shall include specific features to facilitate emergency preparedness and the necessary emergency response facilities on the site where accidents could have significant off-site consequences.

6.117. The inclusion of specific design features for facilitating emergency preparedness shall be considered, depending on the potential hazard deriving from the facility. The need for such design features may be determined by means of analyses of design extension conditions. Acceptable measures shall be based where possible on realistic or best estimate assumptions, methods and analytical criteria.

6.118. The facility shall be provided with adequate storage for emergency equipment (such as Personal Protective Equipment), instrumentation for hazard monitoring and a sufficient number of escape routes, clearly and durably marked, with reliable emergency lighting, ventilation and other services essential to their safe use. The escape routes shall meet the relevant international requirements for

⁵¹Including the accidental addition of moderator or the potential for inadvertently mixing incompatible, hazardous or reactive chemical or radioactive materials.

radiation zoning and fire protection and the relevant national requirements for industrial safety and nuclear security.

6.119. Suitable alarm systems and means of communication shall be provided so that all persons present at the facility and on the site can be warned and instructed, in all plant states. The availability of the means of communication necessary for safety within the facility shall be ensured at all times. Means of communication shall be available in the control room and also in the supplementary control room if there is one. This requirement shall be taken into account in the design and in the diversity of the means of communication selected for use.

Requirement 33: Design provisions for construction

Items important to safety for a nuclear fuel cycle facility shall be designed so that they can be manufactured, constructed, assembled, installed and erected in accordance with established processes that ensure the achievement of the design specifications and the required level of safety.

6.120. In the provision for construction and operation, due account shall be taken of relevant experience that has been gained in the construction of other similar facilities and their associated structures, systems and components. Where best practices from other relevant industries are adopted, such practices shall be shown to be appropriate to the specific nuclear application.

Requirement 34: Qualification of items important to safety

A qualification programme shall be implemented to verify that items important to safety are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life, with due account taken of conditions during maintenance and testing.

6.121. The environmental and service conditions considered in the qualification programme for items important to safety at a nuclear fuel cycle facility shall include the variations in ambient environmental conditions that are anticipated in the design basis⁵² and for identified design extension conditions.

6.122. The qualification programme for items important to safety shall include the consideration of ageing effects caused by environmental factors (such as conditions of vibration, irradiation, humidity or temperature) over the expected service life of the items important to safety. When the items important to safety are subject to natural external events and are required to perform a safety function during or following such an event, the qualification programme shall replicate as far as is practicable the conditions imposed on the items important to safety by the natural event, either by test or by analysis or by a combination of both.

⁵² See also Requirement 28.

6.123. Items essential to the maintenance of criticality safety and items used to lift spent fuel and breeder elements in pools shall be appropriately qualified.

Requirement 35: Design provisions for commissioning

The design shall include features as necessary to facilitate the commissioning process for nuclear fuel cycle facilities.

6.124. All items important to safety shall be designed and arranged so that their safety functions can be adequately inspected and tested, and the items important to safety can be maintained, as appropriate, before commissioning⁵³ and at suitable and regular intervals thereafter, in accordance with their importance. Where possible, items important to safety shall be qualified before the commissioning stage. If it is not practicable to provide adequate testability of a component, the safety analysis shall take into account the possibility of undetected failures of such equipment.

Requirement 36: Design provisions for decommissioning

In the design of a nuclear fuel cycle facility, consideration shall be given to facilitating its ultimate decommissioning, so as to keep the exposure of personnel and the public, arising from decommissioning, as low as reasonably achievable and to ensure adequate protection of the environment, as well as to minimize the amount of radioactive waste generated in decommissioning.

6.125. While ensuring the safe operation of the facility, the design:

- (a) Shall minimize the number and size of contaminated areas to facilitate clean-up in the decommissioning stage;
- (b) Shall choose materials for containment that are resistant to all chemicals in use and that have sufficient wear resistance, to facilitate their decontamination at the end of their lifetime;
- (c) Shall avoid undesired accumulations of chemical or radioactive materials;
- (d) Shall allow remote decontamination, as necessary;
- (e) Shall consider the amenability to processing, storage, transport and disposal of the waste to be generated during the decommissioning stage;
- (f) Shall make provision for the management of relevant knowledge of the design
- (g) Shall make major system components and potential points of contamination, particularly in the facility structure, readily accessible to facilitate decommissioning.

⁵³ In the context of nuclear fuel cycle facilities, commissioning is the process by means of which systems and components, having been constructed, are made operational and verified to be in accordance with the design and to have met the required performance criteria. Commissioning may include a combination of: non-nuclear; non-radioactive; nuclear, and/ or; radioactive testing as appropriate for the facility and the stage of commissioning.

RADIATION PROTECTION

Requirement 37: Design for protection against internal radiological exposure

The design shall ensure that workers, the public and the environment are protected against uncontrolled releases of radioactive material in all plant states. Releases shall be kept within authorized limits in normal operation and acceptable limits in accident conditions.

6.126. In normal operation, internal exposure shall be minimized by design and shall be as low as reasonably achievable. In accordance with a graded approach, the design features for controlling and limiting internal exposure include confinement and leak detection;

- Provision shall be made for preventing the unnecessary release or dispersion of radioactive substances, radioactive waste and contamination at the facility.
- The facility layout shall be designed to ensure that access of operating personnel to areas of possible contamination is adequately controlled.
- Means of monitoring and appropriate alarm systems for atmospheric contamination shall be installed. Mobile or personal air-monitoring systems shall be provided at locations of work with significant quantities of radioactive material.

6.127. Areas occupied by workers shall be classified according to foreseeable levels of surface contamination and atmospheric contamination, and equipment shall be installed in accordance with this classification (Ref. [2]). The need for appropriate provisions for specific operations in contaminated areas shall be taken into account in the design. Portable and installed equipment shall be able to detect surface contamination on people, equipment, products and other objects to verify the effective confinement of radioactive material.

6.128. Facilities shall be provided for the decontamination of operating personnel and equipment.

Requirement 38: Means of confinement

The design shall include means for the dynamic and static confinement of radioactive and associated hazardous materials. Leak detection shall be implemented as appropriate for the control of contamination.

6.129. The nature and number of confinement barriers and their design performance, as well as the design performance of air purification systems, shall be commensurate with the degree of the potential hazards, with special attention paid to the potential dispersion of alpha emitters.

6.130. Containment shall be the primary method for confinement against the spreading of contamination, ensuring that it is kept within limits and for keeping levels of airborne contamination

as low as reasonably achievable. An appropriate number of complementary static and dynamic containment systems shall be provided as determined by the safety analysis:

- (a) The static containment system shall consist of physical barriers between radioactive material and workers or the environment. The number of physical barriers shall be determined on a case by case basis as determined by a safety analysis.
- (b) The dynamic containment system shall be used to create airflow towards areas with higher levels of contamination for treatment before discharge⁵⁴. The static containment shall be designed such that its effectiveness is maintained as far as achievable in case of loss of dynamic confinement.

6.131. Where there are significant quantities of spent fuel or dispersible alpha emitting material (e.g. in MOx fuel fabrication or reprocessing facilities), at least two static barriers shall be required so that, during normal operations, radioactive material is confined inside the first static barrier. The second static barrier shall be designed with features for the control of airborne contamination to minimize the radiation exposures of workers in operational states for the entire lifetime of the facility, and to limit contamination within the facility to the extent practicable.

6.132. Dynamic containment systems in nuclear fuel cycle facilities shall be designed with an appropriately sized ventilation system in areas that have been identified as having significant potential for concentrations of airborne hazardous material in all plant states.

6.133. In the design of dynamic containment systems, account shall be taken of the performance criteria for ventilation and static containment, including the pressure difference between zones, the types of filter to be used, the differential pressure across filters and the appropriate flow velocity for operational states.

6.134. The effectiveness of filters and their resistance to chemicals, humidity, high temperatures of exhaust gases and fire conditions shall be taken into consideration. The build-up of material shall also be taken into consideration. The ventilation system design, including filters, shall facilitate monitoring and testing of performance.

Requirement 39: Design for protection against external radiological exposure

Provision shall be made for ensuring that doses to operating personnel at the facility will be maintained below the dose limits and will be kept as low as reasonably achievable, and that the relevant dose constraints will be taken into consideration.

⁵⁴ In some systems or parts of systems, the direction of airflow or the absence of any airflow may be determined by other factors e.g. the need to prevent ingress of oxygen or for pressurised vessels or locally pressurised systems. Where flammable materials are processed inert gases may be used instead of air to provide the required flows.

6.135. Radiation sources throughout the facility shall be comprehensively identified, and exposures and radiation risks associated with them shall be kept as low as reasonably achievable by a graded application of the principles of protection by design, which are established in Ref. [2].

6.136. The design of the facility shall optimize human occupancy, the layout of equipment and radioactive materials, and shielding equipment to ensure radiation exposures are kept within limits and maintained as low as reasonably achievable in all operational states. The safety benefit from using automation and remote handling shall also be considered with an appropriate assessment of the allocation of function between humans and automation⁵⁵.

6.137. The designer shall classify areas by taking into consideration the magnitude of the expected normal exposures, the likelihood and magnitude of potential exposures, and the nature and extent of the required protection and safety procedures. Access to areas where radiation levels may cause exposures that give rise to high doses for workers shall be restricted and the level of control applied shall be commensurate with the hazards (Ref. [2]).

6.138. Means of monitoring radiation levels shall be provided so that any abnormal conditions would be detected in a timely manner and workers may be evacuated.

6.139. The facility layout shall be such that the doses received by operating personnel during normal operation can be kept as low as reasonably achievable, and due account shall be taken of the necessity for any special equipment to be provided to meet these requirements. As far as practicable, equipment subject to frequent maintenance or manual operation shall be located in areas of low dose rate to reduce the exposure of workers.

6.140. Appropriate design features shall be provided to prevent direct radiation shine paths through and around penetrations in shielding.

Requirement 40: Radiation monitoring systems

Equipment shall be provided at the nuclear fuel cycle facility to ensure that there is adequate radiation monitoring in operational states, design basis accident conditions and, if appropriate, in design extension conditions.

6.141. The design of radiation monitoring systems shall include:

- (a) Stationary dose rate meters for monitoring the local radiation dose rate at places routinely accessible by operating personnel and at other places where the changes in radiation levels in operational states could be such that access is allowed only for certain specified periods of time (e.g. cells for routine maintenance, ejector galleries).

⁵⁵The objective is the optimisation of doses for example increased automation may increase the exposure of maintenance staff at the same time as reducing the exposure of operators. The total exposure could increase, especially if the automation is unreliable.

- (b) Stationary dose rate meters to indicate the general radiation levels at suitable locations of the facility in anticipated operation occurrences, accident conditions and as practicable design extension conditions. The stationary dose rate meters shall provide sufficient information in the appropriate control position that operating personnel can initiate protective and corrective actions if necessary.
- (c) Monitors for measuring the activity of radioactive substances in the atmosphere in those areas routinely occupied by personnel and where the levels of airborne activity may be expected to be such as to require protective measures.
- (d) Stationary equipment and laboratories for determining, in a timely manner, the concentrations of selected radionuclides in fluid process systems and in gas and liquid samples⁵⁶ taken from the facility or the environment in all plant states;
- (e) Stationary equipment for monitoring and controlling effluents prior to or during their discharge to the environment;
- (f) Devices for measuring radioactive surface contamination;
- (g) Installations and equipment needed for measuring doses to and contamination of personnel;
- (h) Based on graded approach and commensurate with the involved risks, radiation monitoring at gates and other possible points of egress from the facility for radioactive material being removed from the facility building without permission or by unintentional contamination.

6.142. Measures shall be taken to prevent the spread of radioactive contamination, including by means of adequate monitoring systems (see also Requirements 46 and 47).

6.143. In addition to monitoring within the facility, arrangements shall also be made to assess exposures and other radiological impacts to determine the radiological consequences of the facility in the vicinity, as necessary.

Requirement 41: Design for criticality safety

The design shall ensure adequate sub-criticality control with sufficient safety margins, under normal operational states and conditions that are referred to as credible abnormal conditions, or conditions included in the design basis.

Prevention

6.144. Criticality safety shall be ensured by means of preventive measures. As far as reasonably achievable, criticality hazards shall be controlled by means of design.

6.145. Methods of ensuring criticality safety in any process shall include, but shall not be limited to, any one of or a combination of:

⁵⁶These may be different process streams and samples for each plant state.

- (a) Passive engineered control involving equipment design;
- (b) Active engineered control involving the use of process control instrumentation;
- (c) Chemical means, such as the prevention of conditions that allow precipitation;
- (d) Reliance on inherently safe processes;
- (e) Administrative controls⁶ to ensure compliance with operating procedures.

6.146. Criticality evaluations and calculations shall be performed on the basis of making conservative assumptions.

6.147. In accordance with national regulations, criticality safety shall be demonstrated in facilities and their surrounding area⁵⁷ where the mass of fissile material could exceed a threshold defined as significant quantity of fissile material. The regulator shall specify the thresholds to be used.

6.148. A rigorous proven method of safety analysis shall be used and defence in depth shall be considered for the prevention of criticality accidents. Safety controls for criticality shall be independent, diverse and robust. Any change to the design or the assumptions that affect processes or activities involving fissile material shall be reassessed for criticality safety.

6.149. For the prevention of criticality by means of design, the double contingency principle shall be the preferred approach. This principle is applied, such that the design for a process must include sufficient safety factors to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible.

6.150. Criticality safety shall be achieved by keeping one or more of the following parameters of the system within subcritical limits under normal operational states and conditions that, in accordance with national regulations, are referred to as (a) credible abnormal conditions, or (b) conditions included in the design basis (e.g. due to fire, flooding or loss of cooling):

- Mass and enrichment of fissile material present in a process;
- Geometry (limitation of the dimensions or shape) of processing equipment;
- Concentration of fissile material in solutions;
- Degrees of moderation;
- Control of reflectors;
- Presence of appropriate neutron absorbers.

6.151. The safety of the design for a facility shall be demonstrated by means of a specific criticality analysis in which the following important factors are considered both singly and in combination:

⁵⁷ Examples of “Area” in this paragraph include an enrichment cascade, a building or a whole site.

- (a) Enrichment: the maximum authorized enrichment in any part of the facility shall be used in all assessments unless the impossibility of reaching this level of enrichment is demonstrated in accordance with the double contingency principle.
- (b) Mass: criticality safety shall be assessed with significant margins.
- (c) Geometry: the analysis shall include the layout of the facility, and the dimensions of pipes, vessels and other process units. The potential for changes in dimensions during operation shall be considered.
- (d) Concentration, density and form of materials: a conservative approach shall be taken. Where applicable, a range of fissile material concentrations for solutions shall be considered in the analysis to determine the most reactive conditions that could occur. Unless the homogeneity of the solution can be guaranteed, the worst case concentration of fissile materials in the processing and storage parts of the facility shall be considered.
- (e) Moderation: the analysis shall consider a range of degrees of moderation to determine the most reactive conditions that could occur.
- (f) Reflection: a conservative assumption concerning reflection shall be made.
- (g) Neutron interaction: consideration shall be given to neutron interaction between all facility units that may be involved, including any mobile unit that may approach the array.
- (h) Neutron absorbers: when taken into account in the safety analysis, and if there is a risk of degradation, the presence and the integrity of neutron absorbers shall be verifiable during periodic inspection.
- (i) Uncertainties in all parameters (e.g. mass, density and geometry) shall be considered in the criticality calculations.

6.152. Computer codes used for demonstrating criticality safety shall be verified and validated (Ref. [12]).

6.153. In the demonstration of criticality safety, account shall be taken of:

- (a) The potential for misdirection, accumulation, overflow and spills of fissile material (e.g. mis-transfer due to human error) or for carry-over of fissile material (e.g. from evaporators);
- (b) The potential for leaks to evaporate, leading to an increase in concentrations, particularly where there is a potential for evaporation to occur before the leak is detected;
- (c) The choice of fire extinguishing media (e.g. water or powder) and the safety of their use shall be addressed;
- (d) The effects of corrosion, erosion and vibration in systems exposed to oscillations, e.g. leaks and changes in geometry. When criticality control of fissile liquid is achieved by geometry, loss of containment shall be anticipated by, for example, the use of criticality safe drip trays or detection of liquid level;

- (e) The potential for internal and external flooding and other internal and external hazards that may compromise measures for criticality prevention;
- (f) The potential use of neutron poisons such as gadolinium or boron shall be addressed, in normal operation (e.g. to increase the safe mass of fissile material in a dissolver), during deviations from normal operation (e.g. dilutions of soluble neutron poisons below a specified limit of concentration) and in accident conditions;
- (g) Transitory configurations of fissile material during movement.

6.154. Particular consideration shall be given to those system interfaces⁵⁸ for which there is a change in the state of the fissile material⁵⁹ or in the criticality control mode. Particular consideration shall also be given to the transfer of fissile material from equipment with a safe geometry to equipment with a geometry not meeting the acceptance criteria.

6.155. If the design of the facility takes into account burnup credit, its use shall be appropriately justified in the criticality safety analysis. Further guidance on criticality control is provided in Ref. [14].

Mitigation

6.156. States have adopted various approaches to mitigation measures for, and consequence assessments of, criticality accidents. The need for the following measures shall be assessed for their suitability:

- (a) The installation of a criticality detection and alarm system to initiate immediate evacuation;
- (b) The identification and marking of appropriate evacuation routes and regrouping areas;
- (c) The provision of appropriate emergency equipment;
- (d) Specific measures to protect the public (see below).

6.157. When designing a new facility, effectiveness of protection measures (see Ref. [7]) of the public against off-site consequences of a criticality accident shall be evaluated. If it is determined that the protection measures cannot be effective due to prompt nature of a criticality accident, adequate mitigation measures (distance, shielding and confinement) shall be considered such that off-site consequences of a criticality accident do not exceed criteria established for temporary public evacuation.

6.158. In addition to the requirements established above the following facility specific requirements shall be met:

⁵⁸ System interfaces may occur in the course of transfer of fissile material between different locations, e.g. between different processes, process vessels, sub-facilities or rooms.

⁵⁹ The state of the fissile material includes, for example, its physical and chemical forms and concentration.

Mixed uranium and plutonium oxide powders

6.159. The safety of the design for a MOX fuel fabrication facility shall be achieved by keeping one or more of the following parameters of the system within subcritical limits under normal operational states and conditions that, in accordance with national regulations, are referred to as credible abnormal conditions, or conditions included in the design basis:

(a) PuO₂ (input):

(i) Mass and geometry in accordance with the safety specification of PuO₂ isotopic composition and moderation;

(ii) Presence of appropriate neutron absorbers.

(b) UO₂ (input): mass and geometry in accordance with the safety specification of UO₂ isotopic composition and moderation.

(c) MOX powder: MOX powder is formed in the fuel fabrication process, and the associated criticality hazard shall be assessed in accordance with the isotopic specification and the PuO₂ content at each stage of the process. Mass, geometry and moderation shall be considered.

Mixed uranium and plutonium liquids

6.160. A reference flow sheet shall be defined. This shall specify compositions and flow rates for active feed material and reagent feed material. Faults relating to incorrect reagent flows or compositions having the potential to impact criticality safety shall be assessed.

Mixtures of powders or liquids containing fissile material

6.161. For laboratories and, if necessary, for solid plutonium waste, the safe mass and geometry (for storage) of plutonium shall be assessed with the isotopic composition as determined above.

6.162. The safety of the design for a MOX fuel fabrication facility shall be demonstrated by means of a specific criticality analysis in which the following important factor is considered: plutonium isotopic composition, PuO₂ content and uranium enrichment (if ²³⁵U > 1%): the maximum authorized compositions in any part of the process shall be used in all assessments unless the impossibility of reaching this Pu composition or content (and uranium enrichment, if needed) is demonstrated in accordance with the double contingency principle.

6.163. A reference composition for the fissile material (reference fissile medium) shall be defined. The criticality safety assessment performed using such a reference shall be a conservative bounding case for the actual composition of the fissile material being handled or processed, e.g. on the basis of its mass, volume and isotopic composition. It shall be ensured by means of the assessment that processes are conducted within the operational limits and conditions.

Requirement 42: Design provisions for decay heat removal

Cooling systems and the necessary support systems shall be provided to remove heat from radioactive decay. The capacity, availability and reliability of cooling systems and their support systems shall be analysed and justified in the safety analysis.

6.164. Cooling systems shall be designed and provided to prevent the release and dispersion of significant quantities of radioactive materials from spent fuel, plutonium and highly active process and storage systems, due to overheating resulting in boiling or loss of containment.

6.165. Alternate heat sinks shall be provided where the safety assessment identifies the potential for widespread consequences resulting from the loss of primary heat sink.

6.166. The loss of power is covered by Requirements 51 and 52.

DESIGN REQUIREMENTS FOR PROTECTION AGAINST NON-RADIOLOGICAL HAZARDS

Requirement 43: Design for control of flammable mixtures and materials

The design shall include features to prevent hazardous reactions of mixtures and materials used or produced in processing.

6.167. The chemistry of any reactive, flammable or highly corrosive materials used or produced in the processing of nuclear materials shall be considered in the safety analysis. Examples of such materials include hydrogen, hydrofluoric acid and red-oil which may be used or produced in processes including dissolution, extraction and fuel manufacture. Such materials may be present deliberately or as by-products e.g. of radiolysis.

6.168. Where these are hazardous, systems and controls shall be provided to:

- (a) Limit the storage of hazardous materials in areas where nuclear material is handled;
- (b) Maintain concentrations of gas mixtures below flammable levels;
- (c) Prevent solvents and their degradation products from undergoing rapid chemical decomposition and highly exothermic reactions in heated equipment;
- (d) Avoid the potential for rapid exothermic reaction and ignition in downstream processes, including waste treatment.

6.169. The capacity, availability and reliability of these systems and controls shall be analysed and justified in the safety analysis report.

Requirement 44: Design measures for preventing fire and explosions

Equipment shall be designed and located, so as to prevent fires and explosions and to minimize their effects

6.170. Items important to safety shall be designed and located, subject to compliance with other safety requirements, so as to minimize the effects of fires and explosions. The necessary ratings of the fire barriers and means of passive protection and physical separation against fires and explosions shall be based on a documented fire hazard analysis⁶⁰ and an explosion hazard analysis for the nuclear fuel cycle facility. The design shall include provisions to:

- (a) Prevent fires and explosions;
- (b) Detect and extinguish quickly those fires that do start, thus limiting the damage caused;
- (c) Prevent the spread of those fires that are not extinguished, and of fire induced explosions, thus minimizing their effects on the safety of the facility.

6.171. Internal fires and explosions shall not challenge redundant trains of safety systems. Firefighting systems shall be automatically initiated as necessary.

6.172. Firefighting systems shall be designed and located so as to ensure that their use or rupture or spurious or inadvertent operation would not increase the criticality risk, would not harm operating personnel, would not significantly impair the capability of items important to safety, and would not simultaneously affect redundant safety groups and thereby render ineffective the measures taken to comply with the single failure criterion⁶².

6.173. Non-combustible or fire retardant and heat resistant materials shall be used wherever practicable throughout the nuclear fuel cycle facility, in particular in locations such as the switch rooms and the control room. Flammable gases and liquids, reactive chemicals, oxidising reagents and combustible materials that could produce or contribute to explosive mixtures shall be kept to the minimum necessary amounts and shall be stored in adequate facilities to keep reacting substances segregated.

6.174. Fires and explosions shall not prevent achievement of the main safety functions or prevent monitoring the status of the facility. These shall be maintained by means of the appropriate incorporation of redundant structures, systems and components, diverse systems, physical separation and design for fail-safe operation.

6.175. The design of inerting systems for the prevention of fire shall ensure their required availability, sustainability and reliability.

⁶⁰ See also requirements 23 and 25.

Requirement 45: Design for protection against toxic chemicals

The design shall ensure that workers, public and the environment are protected against toxic chemical exposures.

6.176. The design shall consider the recommendations established by the IAEA with international organizations for control of toxic chemicals (Refs. [15] and [16]). To avoid health effects from toxic chemicals the design shall follow the hierarchy of prevention, control and mitigation;

- (a) The minimization of inventories;
- (b) The safe storage of hazardous process materials;
- (c) The safe configuration and control over credible changes that may lead to the release of toxic materials;
- (d) Adequate local and facility ventilation;
- (e) The detection and alarm capability for chemical or toxic releases;
- (f) The chemical compatibility of materials that are likely to come into contact;
- (g) Personnel protective equipment to protect against exposures to chemical compounds or toxic materials.

INSTRUMENTATION AND CONTROL SYSTEMS**Requirement 46: Design of instrumentation and control systems**

Instrumentation and control systems shall be provided for controlling the values of all the main system variables that are necessary for safe operation in all operational states. Instrumentation shall provide for bringing the system to a safe state and for monitoring of accident conditions. The reliability, separation and diversity required of I&C systems shall be based on the safety analysis for the system.

6.177. The facility shall be provided with appropriate controls, both manual and automatic as appropriate, to maintain parameters within specified operating ranges. I&C shall be provided for control where timely manual response cannot be guaranteed, to ensure compliance with the specified operational limits and conditions. The safety related I&C shall be designed to withstand events within the design basis and design extension conditions, in accordance with a graded approach.

6.178. The facility shall be provided with the necessary and sufficient indicators and recording instrumentation to provide the operators with an adequate level of situational awareness by monitoring important safety parameters for all plant states. The design shall permit the control of the facility during occurrences and accidents to bring the facility back within normal operational limits or to a safe shutdown state. There shall be adequate separation between hazardous facilities and I&C used for emergency control, see Requirements 49 and 50.

6.179. Adequate means shall be provided for measuring process parameters that are relevant to the safety of the facility, both:

- In normal operation, to ensure that all processes are being conducted within the operational limits and conditions and to provide indication of significant deviations in processes and;
- For detecting and managing accident conditions, such as criticality or adverse effects due to external hazards such as an earthquake or flooding (e.g. fire, release of hazardous materials, loss of support systems).

Instrumentation and control systems for criticality

6.180. I&C systems used to ensure sub-criticality shall be of high quality and shall be calibrated against known standards. Changes to computer codes and data shall be controlled to a high standard by means of the management system.

6.181. Radiation detectors (gamma and/or neutron detectors), with audible and where necessary visible alarms for initiating immediate evacuation from the affected area, shall cover all the areas where significant quantities of fissile material is present, unless national regulations establish exceptions, such as: no reasonably foreseeable set of circumstances can initiate a criticality accident, or; an excessive radiation dose to personnel is not credible

Instrumentation and control systems for hot cells, gloveboxes and hoods

6.182. Hot cells, glove-boxes and hoods shall be equipped with instrumentation and control systems for fulfilling the requirements for a negative pressure.

Chemical hazards

6.183. In facilities handling and processing uranium hexafluoride (UF_6);

- Where UF_6 cylinders have the capability of hydraulic rupture on heating, the temperature during heating shall be limited by means of two independent systems.
- Where there is a potential to heat a UF_6 cylinder to a temperature above that of the UF_6 triple point, the weight of the cylinder shall be verified to be below its fill limit by means of a weighing scale, which shall be identified as important to safety.
- Before heating a UF_6 cylinder, the weight of UF_6 shall be measured and shall be confirmed to be below the fill limit (e.g. by using a second independent weighing scale).

6.184. In areas with a significant chemical hazard (e.g. due to UF_6 , HF or ClF_3) and with limited occupancy, detectors shall be installed unless it can be demonstrated that a chemical release is highly unlikely.

6.185. In diffusion enrichment facilities, in-line contaminant concentration detectors shall be used to avoid uncontrolled chemical reactions between UF_6 and possible impurities.

Requirement 47: Reliability and testability of instrumentation and control systems

All I&C based items important to safety shall be designed and arranged so that their safety functions can be adequately inspected and tested, and the systems important to safety can be maintained

6.186. All I&C based items important to safety shall need to be designed and arranged so that their safety functions can be adequately inspected and tested, and the items important to safety can be maintained, as appropriate, before commissioning and at suitable and regular intervals thereafter in accordance with their importance to safety. If it is not practicable to provide adequate testability of a component, the safety analysis shall take into account the possibility of undetected failures of such equipment⁶¹.

Requirement 48: Design and development of computer based equipment in systems important to safety

If an item is dependent upon computer based equipment, appropriate standards and practices for the development and testing of computer hardware and software shall be established and implemented throughout the service life of the system, and in particular throughout the software development cycle. The entire development shall be subject to a quality management system.

6.187. Hardware and software systems that are part of items shall be demonstrated to be highly reliable, on account of characteristics that include;

- (a) A high quality of, and best practices for, hardware and software shall be used, in accordance with the importance of the system to safety;
- (b) The entire development process, including control, testing and commissioning of design changes, shall be systematically documented and shall be reviewable;
- (c) Software specifically developed for items important to safety shall be tested on a platform that is as realistic as possible, prior to active commissioning, Ref. [12];
- (d) Protection shall be provided against disruption of or interference with system operation that includes isolation from data systems of lower classification.

Requirement 49: Design of control rooms and panels

Where control rooms and/or panels are needed for safety including for emergency response, their accessibility and habitability shall be ensured by design and in accordance with the safety assessment.

⁶¹ See also requirement 28.

6.188. Appropriate measures shall be taken and adequate information shall be provided for the protection of occupants of the control room against hazards such as high radiation levels resulting from accident conditions, release of radioactive material, fire, or explosive or toxic gases. Adequate means of communication between control locations and the emergency centre shall be provided.

EMERGENCY SYSTEMS

Requirement 50: Provision of emergency centre

A safety assessment shall determine the need for an emergency centre, on or near the site, from where an emergency response can be coordinated.

6.189. On a large site with a number of facilities, an appropriately resilient emergency centre that can continue to perform its functions under design extension conditions shall be considered. It shall be demonstrated that control centres are accessible during analysed accidents, or an alternative emergency centre shall be identified. The emergency centre shall be separated from normal control centres. Information about important facility parameters and radiological conditions at the site shall be provided in the emergency centre.

6.190. The emergency centre shall provide means of communication with on-site and off-site emergency response organizations and with appropriate control locations on the site.

6.191. Appropriate measures shall be taken to protect the occupants of the emergency centre against hazards resulting from accident conditions. Where required, the emergency centre shall include the necessary systems and services to permit extended periods of occupation and operation by emergency response personnel.

EMERGENCY POWER SUPPLY

Requirement 51: Design of emergency electrical power supply

The electrical supply systems relied upon by safety functions shall be identified in the safety assessment. The design of electrical supply systems shall ensure their required availability, sustainability and reliability, with emergency electrical supplies where necessary.

6.192. The design of the facility shall include a power supply capable of supplying the necessary power in anticipated operational occurrences, design basis accidents and identified design extension conditions in the event of loss of off-site power.

6.193. The design shall also include features to enable the safe use of non-permanent equipment to restore the necessary power supply.

6.194. For facilities with potentially high hazards (e.g. processing, handling and storing spent fuels), diverse and reliable emergency electrical supplies shall be provided for the identified items. The

restoration of electrical power shall be organised and prioritised to ensure adequate and timely restoration following such a loss of normal electrical supply.

OTHER DESIGN CONSIDERATIONS

Requirement 52: Design of compressed air systems

Compressed air systems relied upon by safety functions shall be identified in the safety analysis and provided.

6.195. The design basis for any compressed air system that services an item important to safety (such as valve actuation) shall specify the quality, pressure and flow-rate of the air to be provided. The design of compressed air systems shall also ensure their required reliability. The provision of auxiliary compressed air tanks shall be considered for items important to safety.

6.196. As required, the instruments for compressed air systems mentioned above shall be used to provide an indication at an appropriate control position in all plant states.

Requirement 53: Design of handling and storage systems for fissile and radioactive materials

The design of a nuclear fuel cycle facility shall include provisions for the safe handling and storage of fissile and radioactive materials.

6.197. Accidents in the handling and storage of fissile and radioactive materials shall be considered in the safety analysis and their severity determined using a graded approach.

6.198. Handling and storage systems for fissile and radioactive materials shall be designed:

- (a) To prevent criticality by a specified margin, by physical means, and preferably by use of geometrically safe configurations, even under conditions of optimum moderation;
- (b) To permit inspection of the fissile and radioactive materials;
- (c) To permit maintenance, periodic inspection and testing of components important to safety;
- (d) To prevent damage to fissile and radioactive materials;
- (e) To prevent the dropping of nuclear materials in transit;
- (f) To provide for the identification of individual packages of fissile and radioactive material;
- (g) To ensure that adequate operating procedures and a system of accounting for, and control of, fissile and radioactive materials can be implemented to prevent any loss of, or loss of control.

6.199. In addition, the fuel handling and storage systems for irradiated fuel shall be designed:

- (a) To permit adequate removal of heat from the fuel in all plant states;
- (b) To prevent causing unacceptable handling stresses on fuel elements or fuel assemblies;

- (c) To prevent the potentially damaging dropping on the fuel of heavy objects such as spent fuel casks, cranes or other objects;
- (d) To permit safe keeping of suspect or damaged fuel elements or fuel assemblies;
- (e) To control levels of soluble absorber if this is used for criticality safety;
- (f) To facilitate maintenance and future decommissioning of fuel handling and storage facilities;
- (g) To facilitate decontamination of fuel handling and storage areas and equipment when necessary;
- (h) To facilitate the removal of fuel from storage and its preparation for transportation.

6.200. Where a water pool is used for storage of spent fuel or breeder elements, the design of the facility shall prevent the uncovering of assemblies in all operational states, so as to practically eliminate the possibility of early or large radioactive releases and to avoid high radiation fields on the site. The design of the facility shall provide:

- (a) The necessary cooling capabilities for self-heating materials;
- (b) Features to prevent the uncovering of fuel assemblies in the event of a leak or a pipe break;
- (c) Reliable level monitoring with means to restore the water inventory.

6.201. The design shall also include features to enable the safe use of non-permanent equipment to ensure sufficient water inventory for the long term cooling of spent fuel and for providing shielding against radiation⁶².

6.202. The design shall include the following:

- (a) Means for monitoring and controlling the coolant temperature for all plant states that are of relevance for self-heating materials;
- (b) Means for monitoring and controlling the activity in water and in air for operational states and means for monitoring the activity in water and in air for accident conditions that are of relevance for a spent fuel pool;
- (c) Means for monitoring and controlling the coolant chemistry for operational states.

6.203. Wherever possible, movements (lifts) shall be inherently safe e.g. at low height and avoiding sensitive equipment. Handling systems shall be designed to reduce the frequency and consequences of accidents in transit, in accordance with an analysis of their safety.

⁶²Including non-permanent equipment stored off the site

Requirement 54: Design for process chemistry monitoring and analysis

The design shall incorporate features for obtaining, by analysis or by monitoring, the chemical and radiochemical characteristics of various materials needed for safety

6.204. Features shall be provided in the design to ensure that the chemistry of all processes is being conducted within the operational limits and conditions. The design shall ensure samples are representative with preference given to techniques that minimise occupational doses and waste generation and provide results in a timely manner. Facilities for obtaining samples shall be designed to ergonomic principles.

7. CONSTRUCTION

Requirement 55: Construction programme

Items important to safety shall be constructed, assembled, installed and erected in accordance with established processes that ensure that the design specifications and intent are met. The safety implications of design changes during construction shall be assessed and documented.

7.1. The construction of a nuclear fuel cycle facility shall start only after the operating organization has verified that the main safety issues in the design have been resolved and demonstrated conformity with the relevant regulatory requirements. The responsibility for ensuring that the construction is in accordance with the design lies with the operating organization.

7.2. For large or complex facilities, authorization by the regulatory body may be granted in several stages. Each stage may have a hold point and regulatory agreement may be necessary to proceed to the next stage. The extent of involvement by the regulatory body during construction shall be commensurate with the potential hazards of the facility.

7.3. Before construction begins, the operating organization shall make adequate arrangements with the selected contractor(s) concerning the responsibility for ensuring safety during construction and the identification and control of any adverse impacts of the construction activities on facility operations and vice versa.

7.4. Records shall be maintained in accordance with the management system to demonstrate that the facility and its equipment have been constructed in accordance with the design specifications. Quality records for construction activities shall be sampled and checked by the operating organization, using a graded approach.

7.5. The construction of large or complex nuclear fuel cycle facilities can take a number of years and construction workers, including engineers and architects, may move away to other work and be

replaced. Knowledge and experience relating to construction shall be maintained throughout the construction period and, as necessary, through commissioning and operating stages.

7.6. Arrangements shall be established to ensure that the ‘as built’ documents (including engineering drawings) of the facility are provided by the constructors to the operating organization. Following construction of the facility, the operating organization shall review the as built documents to confirm that the design intent has been met and the safety functions specified will be fulfilled⁶³.

7.7. The operating organization shall, as required, seek agreement by the regulatory body to proceed to the commissioning stage.

8. COMMISSIONING

Requirement 56: Commissioning programme

The operating organization shall ensure that a commissioning programme for the nuclear fuel cycle facility is established and implemented. The programme shall be subjected to regulatory approval prior to its implementation.

8.1. An adequate commissioning programme shall be prepared for the testing of nuclear fuel cycle facility components and systems after their construction or modification to demonstrate that they are in accordance with the design objective and meet the performance criteria. The commissioning programme shall cover the full range of facility conditions required in the design. The commissioning programme shall establish the organization and responsibilities for commissioning, the commissioning stages, the suitable testing of structures, systems and components on the basis of their importance to safety, the test schedule, the commissioning procedures and reports, the methods of review and verification, the treatment of deficiencies and deviations, and the requirements for documentation.

8.2. The requirements on commissioning programme as established by this Section shall also apply to the restart of existing facilities (or processes within facility) after a prolonged shutdown period, as advised by the safety committee.

Organization and responsibilities for commissioning

8.3. The operating organization, designers and manufacturers shall be involved in the preparation and implementation of the commissioning programme. The commissioning process shall involve co-operation between the operating organization and the supplier(s)/constructor(s) to ensure an effective means of familiarizing the operating organization with the characteristics of the facility.

⁶³ For nuclear fuel cycle facilities, although commissioning is the principle means to ensure that the facility meets the design intent, a number of Member States also place high reliance on documentary evidence e.g. the review of ‘as built’ documents, and other quality assurance documentation to demonstrate, in particular, the delivery of the first level of defence in depth, as far as practicable, as an on-going process during construction e.g. the checking of x-ray or other non-destructive testing records for welding.

8.4. The operating organization shall ensure that interfaces and the communication lines between different groups (i.e. groups for design, for construction, contractors, for commissioning and for operations) shall be clearly specified and controlled.

8.5. Authorities and responsibilities shall be clearly specified and shall be delegated to the individuals and groups performing the commissioning activities. The operating organization shall be responsible for ensuring that construction activities are of appropriate quality and that completion data on commissioning activities and comprehensive baseline data, documentation or information are provided. The operating organization shall also be responsible for ensuring that the equipment supplied is manufactured under a management programme that includes inspection for proper fabrication, cleanliness, calibration and verification of operability.

8.6. During construction and commissioning, the facility shall be monitored, preserved and maintained so as to protect facility equipment, to support the testing stage and to maintain conformity with the safety analysis report.

8.7. During construction and commissioning, a comparison shall be carried out between the as built plant and its design parameters. A comprehensive process shall be established to address non-conformities in design, manufacturing, construction and operation. Resolutions to correct differences from the initial design and non-conformities shall be documented.

8.8. The results and analyses of tests directly affecting safety shall be made available to the safety committee (or equivalent) and the regulatory body for review and permissioning as appropriate. Liaison shall be maintained between the regulatory body and the operating organization throughout the commissioning process in accordance with established procedures.

Commissioning tests and stages

8.9. Commissioning tests shall be arranged in functional groups and in a logical sequence, and, as far as is reasonably achievable, shall cover all planned operational aspects. No test sequence shall proceed unless the previous required steps have been successfully completed. The point at which the safety evaluation of modifications is transferred from a design stage evaluation process to an operation stage evaluation process shall be specified. Cold commissioning includes all commissioning and inspection activities with and without the use of non-active materials, before the introduction of radioactive material. Hot commissioning begins with the introduction of radioactive material.

8.10. Adequate measures shall be put in place to address changes in personnel and equipment, containment, criticality safety, and radiation controls and protection arrangements which are normally expected during hot commissioning.

8.11. When the direct testing of safety functions is not practicable, alternative methods of adequately demonstrating their performance shall be made with appropriate approval in accordance with national requirements. This is particularly applicable to fuel reprocessing facilities.

8.12. The following activities shall, as a minimum, be performed during cold commissioning:⁶⁴

- Verification of safety functions which cannot be verified during construction or during hot commissioning, or those which are necessary to be confirmed before going to the hot commissioning stage;
- Confirmation of the performance of shielding and confinement systems, including the weld quality of static containment;

Confirmation of the performance of criticality safety controls;

8.13. The performance of criticality safety controls shall be confirmed at appropriate stages in the commissioning as follows;

(a) Before hot commissioning:

- Demonstration of the availability of criticality detection and alarm systems;
- Demonstration of the performance of emergency shutdown systems.
- Emergency preparedness and response training, verification, validation and exercises (Ref. [7]).

(b) During hot commissioning (and the early years of operation, as practicable):

- Verification of items which cannot be verified during cold commissioning, or which can be verified more effectively during hot commissioning than cold commissioning;
- Verification that actual external and internal doses to workers are consistent with the hypothesis and calculations performed during the design;
- Verification that actual discharges are consistent with the calculated ones and the performance of discharge reduction and control systems.

Commissioning procedures and reports

8.14. Procedures shall be prepared, reviewed and approved for each commissioning stage prior to the commencement of tests for that stage. Commissioning activities shall be performed in accordance with approved procedures. If necessary, the procedures shall include hold points for the notification and involvement of the safety committee, outside agencies, manufacturers and the regulatory body.

8.15. The commissioning programme shall include provisions and procedures for audits, reviews and verifications intended to ensure that the programmes have been conducted as planned and that its

⁶⁴ Tests carried out in the construction stage may also be included in accordance with national regulations. For some facilities, a warm or 'trace active' stage may be added.

objectives have been fully achieved. Provisions shall also be included for resolving any deviation or deficiency that is discovered during the commissioning tests.

8.16. Reports covering the scope, sequence and expected results of these tests shall be prepared in appropriate detail and in accordance with the management system requirements. The reports shall cover the following:

- (a) The purpose of the tests, and acceptance criteria;
- (b) The safety precautions, prerequisites and provisions required necessary during the tests;
- (c) The test procedures;
- (d) The test reports, including a summary of the data collected and their analysis, an evaluation of the results, the identification of deficiencies, if any, and implementation of any necessary corrective actions.

8.17. The results of all commissioning tests, whether conducted by a member of the operating organization or a supplier, shall be made available to the operating organization and shall be retained for the lifetime of the facility.

8.18. The commissioning report, produced on conclusion of the commissioning, shall identify any updates required to the safety case and any changes made to safety measures or work practices as a result of the results of commissioning.

8.19. In addition to the requirements established above, the following facility specific requirements shall be met:

Mixed oxide fuel fabrication facilities

8.20. Plutonium or 'hot processing' commissioning requires major changes in personnel and equipment, containment, criticality, staff education and radiation control arrangements:

- For the workers, the safety culture shall be enhanced so as to ensure safe operation with plutonium.
- The management shall ensure that both the facility and the workers are fully ready for the change before it is implemented.

Reprocessing facilities, cold and hot commissioning

8.21. The following activities shall, as a minimum, be performed:

- Confirmation of the performance of shielding and confinement systems, including confirmation of the weld quality of the static containment;
- Confirmation, where practicable, of the performance of criticality control measures;
- Demonstration of the availability of criticality detection and alarm systems;

- Demonstration of the performance of emergency shutdown systems;
- Demonstration of the availability of the emergency power supply;
- Demonstration of the availability of any other support systems, e.g. compressed air supply and cooling.

8.22. By the end of hot (or ‘active’) commissioning, all the items important to safety shall be made operational and verified to be in accordance with the design and to have met the required performance criteria for active operations and all operational assumptions in the safety analysis confirmed. Any exceptions shall be justified in the safety case for operations.

8.23. During commissioning, operational limits and conditions, and significant parameters shall be confirmed, as shall acceptable variation in values due to facility transients and other small perturbations. Any margins necessary to allow for the precision of measurements or the response times of equipment shall be determined and incorporated in control, alarm and safety trip setting and operational limits and conditions as necessary.

9. OPERATION

ORGANIZATION

Requirement 57: Responsibilities of the operating organization

The operating organization shall have the prime responsibility for safety in the operation of a nuclear fuel cycle facility.

9.1. The prime responsibility for safety shall be assigned to the operating organization of the nuclear fuel cycle facility. It includes the responsibility for supervising the activities of all other related groups, such as designers, suppliers, manufacturers and constructors, employers and contractors, as well as the responsibility for operation of the facility by the operating organization itself. The operating organization shall carry out this responsibility in accordance with the facility management system (Ref. [5]).

9.2. The operating organization shall establish an appropriate management structure for the nuclear fuel cycle facility and shall provide all the necessary infrastructure for operations to be conducted safely. The operating organization shall ensure that adequate resources are available for all functions relating to the safe operation and utilization of the nuclear fuel cycle facility, such as criticality safety, maintenance, periodic testing and inspection, radiation protection, application of the management system and other relevant supporting activities, and shall take into account industrial hazards including, in particular, chemical safety and emergency provisions.

9.3. The operating organization shall ensure that safety related interdependences between facilities on the same site are considered. Boundaries shall be unambiguously defined and boundary responsibilities shall be clearly specified and effective communication routes shall be established.

9.4. As necessary, and in accordance with national regulations and international standards, a dedicated organization and specific rules for on-site transport shall be established.

9.5. The operating organization shall establish and implement a radiation protection programme to ensure that all activities involving radiation exposure or potential exposure are planned, supervised and carried out to achieve the aims stated in this Section. The operating organization shall ensure that adequate measures are in place to provide protection against radiological hazards arising from modifications to the facility.

9.6. In collaboration with designers and suppliers, the operating organization shall have overall responsibility for the satisfactory completion of the commissioning programme (see Section 8), where testing cannot be completed during commissioning (e.g. actual doses to personnel and environmental discharge control measures).

9.7. The operating organization shall prepare periodic summary reports on matters relating to safety as required by the regulatory body that shall be reviewed by the safety committee and submitted to the regulatory body if so required.

9.8. The operating organization shall ensure that:

- (a) An adequate safety analysis report is prepared and kept up to date;
- (b) An integrated management system is established and implemented (see Section 4);
- (c) Safety culture is fostered in the organization to ensure that the attitudes of personnel and the actions and interactions of all individuals and organizations are conducive to safe operation;
- (d) The commissioning process demonstrates that the design requirements have been met and that the facility can be operated in accordance with the design assumptions;
- (e) Emergency plans and procedures are established and implemented;
- (f) The facility is operated and maintained in accordance with the safety analysis and operational limits and conditions and operating procedures by suitably qualified and experienced personnel;
- (g) Sufficient qualified personnel are available to meet the minimum staffing requirements for the various disciplines required to ensure safe operation for all plant states of the nuclear fuel cycle facility, as specified in the safety assessment report and including emergencies;
- (h) Personnel with responsibilities relating to safe operation are adequately trained, and a training and retraining programme is established, implemented and kept up to date and periodically reviewed to verify its effectiveness;

- (i) Adequate, controlled and verified procedures are produced and distributed in accordance with the established management system for all plant states including emergency procedures and guidance for design extension conditions;
- (j) Adequate facilities and services are available for all plant states;
- (k) Information on events with safety significance are appropriately reported, including any investigation of such events and the corrective actions intended, to the regulatory body and shared with the personnel;
- (l) The facility management is provided with sufficient authority and resources to enable it to fulfil its duties effectively;
- (m) The fissile and radioactive materials that are utilized or generated are controlled adequately and in accordance with operational limits and conditions;
- (n) Operational experience, including information on events and operating experience at similar facilities, is carefully examined for any precursor signs of trends adverse to safety, so that actions⁶⁵ can be taken to prevent serious adverse conditions arising and the recurrence of accidents.

9.9. The operating organization may delegate to other organizations work necessary for discharging its responsibilities, in accordance with the regulatory requirements, but the overall responsibility and control shall be retained by the operating organization.

9.10. The operating organization shall provide suitable training in radiation protection and the safety consequences of their work to the operating personnel, including technical support personnel.

Requirement 58: Structure and functions of the operating organization

The structure of the operating organization and the functions, roles and responsibilities of its personnel shall be established and documented taking into account graded approach.

9.11. Functional responsibilities, lines of authority, and lines of internal and external communication for the safe operation of the nuclear fuel cycle facility in all plant states shall be clearly specified in writing. The functions and responsibilities for the key positions within the operation organizational chart of the facility shall be established. In particular, the operating organization shall clearly establish lines of authority and communications between the facility management, the safety committee⁶⁶, nuclear criticality safety staff, radiation protection personnel, maintenance groups, and the management system personnel.

9.12. Documentation of the organizational structure and of the arrangements for discharging responsibilities shall be made available to the staff and to the regulatory body. The structure of the

⁶⁵ Including training of the workers, as necessary.

⁶⁶ See footnote to requirement 6 concerning multiple safety committees

operating organization shall be specified so that all roles that are important for safe operation are specified and described. Proposed organizational changes to the structure and associated arrangements, which might be of importance to safety, shall be evaluated in advance by the operating organization. Where required by the Member State's regulations, proposals for such organizational changes shall be submitted to the regulatory body for approval.

9.13. The operating organization shall be responsible for ensuring that the necessary knowledge⁶⁷, skills, safety culture and safety expertise are sustained at the nuclear fuel cycle facility, and that long term objectives for human resources policy are developed and are met.

9.14. The operating organization shall be responsible for ensuring that the staff selected for facility operation are given the training and retraining necessary for the safe and efficient operation of the facility and that this training and retraining is appropriately evaluated. There shall be adequate training in the procedures to be followed for all plant states.

Requirement 59: Operating personnel

The operating organization shall ensure that the nuclear fuel cycle facility is staffed with competent managers and sufficient qualified personnel for the safe operation of the plant.

9.15. The operating organization shall assign direct responsibility and authority for the safe operation of the nuclear fuel cycle facility to the senior management. The senior management shall have overall responsibility for the safety of all aspects of operation, training, maintenance, periodic testing, inspection, utilization and modification of the nuclear fuel cycle facility. Discharge of this responsibility shall be the primary duty of the senior management, see below.

9.16. The senior management shall clearly document the duties, the responsibilities, the necessary experience and the training requirements of operating personnel, and their lines of communication. Other personnel involved in the operation or use of the nuclear fuel cycle facility (e.g. technical support personnel and experimenters) shall also have their duties, responsibilities and lines of communication clearly documented.

9.17. The senior management shall specify the minimum staffing requirements for the various disciplines required to ensure safe operation for all operational states of the nuclear fuel cycle facility in accordance with the operational limits and conditions. These requirements include both the number of personnel and the duties for which they are required to be authorized. A qualified person with responsibility for the direct supervision of the operation of the nuclear fuel cycle facility shall be clearly identified by the operating organization at all times. The availability of the staff that would be required to deal with accident conditions shall also be specified (Ref. [7]).

⁶⁷ Sometimes called "knowledge management", see Requirement 65.

9.18. The senior management shall be responsible for ensuring that the staff selected for control room duties are given the training and retraining necessary for the safe and efficient operation of the facility and that this training and retraining is appropriately evaluated. There shall be adequate training in the procedures to be followed for all plant states, see Requirement 61 and Ref. [7]).

9.19. Notwithstanding the presence of independent radiation protection personnel, the operating personnel, including technical support personnel, shall be given suitable training in radiation protection before the start of their duties. Periodic refresher training in operational radiation protection shall be implemented.

9.20. The detailed programme for the operation and utilization of the nuclear fuel cycle facility shall be prepared in advance and shall be subject to the approval of the senior management.

9.21. The senior management shall be responsible for and shall make arrangements for all the activities associated with nuclear safety, including the handling of fissile material.

9.22. The senior management shall periodically review the operation of the nuclear fuel cycle facility and shall take appropriate corrective actions in regard of any problems identified. The senior management shall seek the advice of the safety committee(s) or shall call upon specialist advisors to review important safety issues arising in the commissioning, operation, maintenance, periodic testing and inspection, and modification of the facility.

9.23. The operating personnel shall operate the facility in accordance with the approved operational limits and conditions and operating procedures (Requirements 61 and 62). The number and the type of operating personnel required will depend on design aspects of the nuclear fuel cycle facility, such as the facility type, throughput, the operational cycle and the utilization.

9.24. All licensed or authorized operating personnel shall have the authority to shut down the nuclear fuel cycle facility in the interest of safety.

9.25. A maintenance group shall be established by the operating organization to implement the programmes for maintenance, periodic testing and inspection (Requirement 68).

9.26. All safety significant aspects of operation, maintenance, periodic testing, inspection, utilization and modification of the nuclear fuel cycle facility) shall be carried out by authorised operating personnel (which may include personnel from external organizations).

Radiation protection personnel

9.27. The radiation protection programme shall include the establishment within the operating organization of a radiation protection group with the appointment of qualified radiation protection

officers who are technically competent in radiation protection matters and knowledgeable about the radiological aspects of the design, operation and hazards of the facility.

9.28. The radiation protection personnel shall provide advice to the operating personnel and shall have access to the levels of management within the operating organization with the authority to establish and enforce operational procedures.

Nuclear criticality safety staff

9.29. For nuclear fuel cycle facilities where there is the potential for an accidental criticality the operating organization shall appoint qualified nuclear criticality safety staff who are knowledgeable about the physics of nuclear criticality and the associated safety standards, codes and best practices, and who are familiar with the facility operations. This function shall, to the extent necessary, be independent of the operations management.

9.30. The nuclear criticality safety staff: (i) shall give assistance for the training of personnel; (ii) shall provide technical guidance and expertise for the development of operating procedures; and (iii) shall check and validate all operations that may require criticality safety controls.

Waste and effluent specialists

9.31. There shall be sufficient qualified staff to ensure that policies for the management of waste and discharge of effluents are carried out in accordance with authorized limits and principles of radioactive waste minimization.

Additional technical support personnel

9.32. Additional technical personnel such as training officers, safety officers and management system officers shall follow the safety rules and procedures specified by the operating organization.

MANAGEMENT OF OPERATIONAL SAFETY

Requirement 60: Operational limits and conditions

The operating organization shall approve the set of operational limits and conditions derived from the safety analysis. The operating organization shall ensure that the nuclear fuel cycle facility is operated in accordance with the set of operational limits and conditions.

9.33. The facility shall be operated within a comprehensive set of operational limits and conditions to prevent situations arising that could lead to anticipated operational occurrences or accident conditions, and to mitigate the consequences of such events if they do occur.

9.34. The operating organization shall maintain sufficient records to demonstrate compliance with operational limits and conditions, see Requirement 65.

Operation outside operational limits or conditions

9.35. In the event that the operation of the facility deviates from one or more operational limits and conditions, remedial actions shall be taken and the regulatory body shall be notified.

9.36. Actions shall be specified to be taken by the operating staff within a specified time if a limiting condition for safe operation is violated. The facility management shall conduct an investigation of the cause and the consequences and shall take appropriate actions to prevent a recurrence. The regulatory body shall be notified in a timely manner.

Safety limits

9.37. Safety limits shall be maintained to provide adequate protection of the physical barriers against radiation and uncontrolled release of radioactive material.

Safety system settings

9.38. For each parameter for which a safety limit is required and for other important safety related parameters, there shall be a system that monitors the parameter and provides a signal that can be utilized in an automatic mode to prevent that parameter from exceeding the set limit. The point for this protective action that will provide the minimal acceptable safety margin is the safety system setting. This safety margin will allow for, among other things, behaviour in system transients, the equipment response time and inaccuracy of the measuring devices.

Limiting conditions for safe operation

9.39. Limiting conditions for safe operation are conditions established to ensure that there are acceptable margins between normal operating values and the safety system settings. The setting of limiting conditions for safe operations shall be set to avoid the undesirably frequent actuation of safety systems. Limiting conditions for safe operations shall include limits on operating parameters, requirements relating to minimum operable equipment and minimal staffing levels, and actions to be taken by operating personnel to avoid the operation of the safety system.

9.40. Procedures shall be established for authorising the transfer of hazardous (radioactive, fissile or chemically reactive) materials between buildings according to a positive acceptance of the material by operators in the receiving building before transfer commences.

Periodic testing and surveillance

9.41. Requirements shall be established for the frequency and scope of periodic testing and surveillance for all items important to safety to ensure compliance with operational limits and conditions, safety system settings and limiting conditions for safe operation.

9.42. The requirements for periodic testing and surveillance shall include a specification that clearly states the applicability, the frequency of periodic testing and surveillance and the acceptance criteria.

In order to provide operational flexibility, the specification concerning frequency shall state average intervals with a maximum that shall not be exceeded. Any failure to comply with these requirements shall, in a timely manner, be recorded, investigated, reported to the regulatory body in accordance with national requirements and effective, improvement action taken to prevent recurrence.

Administrative control requirements

9.43. The operational limits and conditions shall include administrative requirements or controls concerning organizational structure and the responsibilities for key positions in the safe operation of the facility, staffing, the training and retraining of facility personnel, review and audit procedures, modifications, records and reports, and required actions following a violation of an operational limits and condition.

9.44. The operating organization shall ensure maintenance of and compliance with administrative controls⁶ specified in the safety assessment report and operational limits and conditions including those for actions required in the event of any deviation from these requirements.

Requirement 61: Training, retraining and qualification

The operating organization shall ensure that all activities that may affect safety are performed by suitably qualified and competent persons.

9.45. The operating organization shall clearly define the requirements for qualification and competence to ensure that personnel performing safety related functions are capable of safely performing their duties. Certain operating positions may require formal authorization or a licence.

9.46. Suitably qualified personnel shall be selected and shall be given the necessary training and instruction to enable them to perform their duties correctly for all plant states, in accordance with the appropriate procedures.

9.47. A suitable⁶⁸ training and retraining programme shall be established and maintained for the operating personnel. The training programme shall include provision for periodic confirmation of the competence of personnel and for refresher training on a regular basis. The refresher training shall also include retraining provision for personnel who have had extended absences from their authorized duties.

9.48. The training shall promote safety culture and shall emphasize the importance of safety in all aspects of the facility, including its design features, safety analysis, human and organizational factors, operational limits and conditions, operating procedures, radiation protection (including contamination control), criticality safety, emergency preparedness and response, and specific industrial safety hazards

⁶⁸ For example training based on the records and reports generated under **Requirement 65**.

such as chemical and fire hazards. The scope of training on nuclear and non-nuclear hazards shall be commensurate to the hazard posed by the nuclear fuel cycle facility.

9.49. Specific training and drills for operating personnel, external firefighters and rescue staff (emergency response) shall be provided relevant to their response to fire or explosion at the facility. The training and retraining programmes shall be conducted in accordance with potential hazards of the facilities and the processes.

9.50. Specific attention shall be paid to the qualification and training of personnel for dealing with radiological hazards (mainly criticality and contamination) and specific conventional hazards such as chemical hazards and fire hazards.

9.51. Training, training programmes, training material and training outcomes shall be subject to review and audit in accordance with the established management programme.

9.52. In addition to the requirements established above, the following facility specific requirements shall be met:

Mixed oxide fuel fabrication facilities

9.53. Special attention shall be paid to training workers in glovebox operations, including actions to be taken if contamination occurs.

Conversion facilities and uranium enrichment facilities

9.54. The operators shall be given training in the safe handling and processing of large quantities of UF₆ and other hazardous chemicals, the level of detail of which shall be commensurate with the risks associated with the operation. For releases of UF₆ and other chemical adequate training shall be given to all site personnel to take appropriate action in the event of a chemical release.

Fuel cycle research and development facilities

9.55. Researchers as well as operators shall be qualified and trained to handle radioactive material and to conduct tests and experiments.

Requirement 62: Carrying out safety related activities

The operating organization shall ensure that all safety related activities are adequately analysed and controlled to ensure that the risks associated with harmful effects of ionizing radiation are kept as low as reasonably achievable.

9.56. All operational activities shall be assessed for the potential risks associated with harmful effects of ionizing radiation. The level of assessment and control shall depend on the safety significance of the task.

9.57. If there is a need to conduct a non-routine operation or test that is not covered by existing operating procedures, a specific safety review shall be carried out and a special procedure shall be developed and subject to approval in accordance with the established procedures for modifications.

Requirement 63: Operational ageing management

The operating organization shall ensure that an effective ageing management programme is implemented to manage the ageing of items important to safety so that the required safety functions of structures, systems and components are fulfilled over the entire operating lifetime of the nuclear fuel cycle facility.

9.58. The ageing management programme shall determine the consequences of ageing and the activities necessary to maintain the operability and reliability of structures, systems and components. The ageing management programme shall be coordinated with, and be consistent with, other relevant programmes, including the programme for in-service inspections, periodic safety review⁶⁹ and maintenance. A systematic approach shall be taken to provide for the development, implementation and continuous improvement of ageing management programmes.

9.59. Where details of the characteristics of materials are unavailable, a suitable material surveillance programme shall be implemented by the operating organization. Results derived from this programme shall be used to review the adequacy of the facility design at appropriate intervals.

9.60. The maintenance and replacement of equipment shall be adjusted in accordance with the conclusions of the ageing management programme. The design life of equipment shall be considered in safety assessments for extended operation.

Requirement 64: Operational control of modifications

The operating organization shall establish and implement a management programme for control of modifications to the facility

9.61. The operating organization shall have the overall responsibility for all safety aspects of the preparation and performance of modifications. It may assign or subcontract the execution of certain tasks to other organizations but it shall not delegate its responsibilities. In particular, the operating organization shall be responsible for the management of the proposed modification project, in which the senior management shall participate according to established procedures. For major projects this shall include the setting of the objectives and the structure of the project, the appointment of a project manager, the specification of responsibilities and the allocation of adequate resources. In addition, before the project commences, it shall establish and follow approved procedures for controlling modification projects.

⁶⁹See Requirement 5.

9.62. The operating organization shall be responsible for ensuring the following:

- (a) Ensuring that, for multi-facility sites, a proposed modification in one nuclear fuel cycle facility will not adversely affect the operability or safety of associated or adjacent facilities;
- (b) Safety analyses of the proposed modification are conducted;
- (c) The relevant safety documentation (e.g. safety assessment report and operational limits and conditions) of the facility is followed;
- (d) The relevant licensing documentation of the modification is prepared and the associated requirements for review and approval are met. These may include the requirement to obtain the approval of the regulatory body;
- (e) Proper safety precautions and controls are applied with regard to all persons involved in the performance of the modification, and with regard to the public and the environment;
- (f) The management system is applied at all stages in the preparation and performance of the modification to ascertain whether all applicable safety requirements and criteria have been satisfied;
- (g) All personnel who will be involved in making a proposed modification are suitably trained, qualified and experienced for the task and, if necessary, trained in advance in the effect of this modification on facility operation and the safety characteristics of the facility;
- (h) All documents affected by the modification that relate to the safety characteristics of the facility, such as the safety assessment reports, the operational limits and conditions and the relevant procedures for operation, maintenance and emergencies, shall be promptly updated as necessary;
- (i) Appropriate commissioning is carried out, the results recorded and assessed and any findings incorporated in the appropriate documentation including changes to safety assessment as required;
- (j) In accordance with national requirements the regulatory body is informed of modification in advance and, where necessary, authorization to with the modification is sought and obtained before changes are made.

9.63. Proposals for the modification of the facility shall be categorized and relevant criteria for this categorization shall be established, taking into account graded approach. Proposals for modification shall be categorized either according to the safety significance of the proposal or on the basis of a statement of whether or not the proposed change will reduce the safety margins or challenge current operational limits and conditions or other significant acceptance criteria (e.g. operator collective or individual doses).

9.64. Modification projects having major safety significance shall be subjected to safety analyses and to procedures for design, construction and commissioning that are equivalent to those described in Sections 6, 7 and 8 for the facility itself.

9.65. In implementing modification projects for nuclear fuel cycle facility, the radiation exposure of the workers involved shall be kept as low as reasonably achievable.

9.66. Temporary modifications shall be limited in time and number to minimize the cumulative safety significance. Temporary modifications shall be clearly identified at their location and at any relevant control position. The operating organization shall establish a formal system for informing relevant personnel in good time of temporary modifications and of their consequences for the operation and safety of the facility.

Requirement 65: Records and reports

The operating organization shall establish and maintain a system for the control of records and reports in the nuclear fuel cycle facility.

9.67. For the safe operation of the facility, the operating organization shall retain all essential information concerning the design, construction, commissioning, current configuration and operation of the facility. This information shall be maintained up to date throughout the operational stage of the facility and shall be kept available during decommissioning. Such information includes site data and environmental data, design specifications, details of the equipment and material supplied, as-built drawings, information on the cumulative effects of modifications, logbooks, operating and maintenance manuals and management system documents.

9.68. Procedures consistent with the integrated management system shall be developed for the generation, collection, retention and archiving of records and reports. Information entries in logbooks, checklists and other appropriate records shall be properly dated and signed.

9.69. Records of non-compliance and the measures taken to return the facility to compliance shall be prepared and retained and shall be made available to the regulatory body. The operating organization shall ensure that records are retained for their specified retention periods.

9.70. The arrangements made for storing and maintaining records and reports shall be in accordance with the integrated management system. The document management system shall be designed to ensure that obsolete documents are archived and that personnel use only the latest version of each document. The off-site storage (e.g. in the emergency centre) of documents for access in an emergency shall be considered.

PLANT OPERATIONS

Requirement 66: Operating procedures

Operating procedures shall be developed that apply comprehensively for normal operation, anticipated operational occurrences and accident conditions, in accordance with the policy of the operating organization and the requirements of the regulatory body.

9.71. Operating procedures shall be developed for all safety related operations that may be conducted over the entire lifetime of the facility.

9.72. Operating procedures shall be developed by the operating organization, in co-operation whenever possible with the designer and manufacturer and with other staff of the operating organization, including radiation protection staff. Operating procedures shall be consistent with and useful in the observance of the operational limits and conditions and shall be prepared in accordance with management system procedures that govern the format, development, review and control of such procedures.

9.73. The operating procedures shall be reviewed and updated periodically on the basis of the lessons learned in using the procedure, and, in accordance with the management programme. They shall be readily available at the point of use.

9.74. All personnel involved in the operation and use of the facility shall be adequately trained in the use of these procedures, as relevant to their duties.

9.75. When activities that are not covered by existing procedures are planned, an appropriate procedure shall be prepared and reviewed and shall be subject to appropriate approval before the operation is started. Additional training of relevant staff in these procedures shall be provided.

Requirement 67: Operational housekeeping and material condition

The operating organization shall develop and implement programmes to maintain a high standard of material conditions, housekeeping and cleanliness in all working areas.

9.76. Administrative controls⁶ shall be established to ensure that operational premises and equipment are maintained, well lit and accessible, and that temporary storage is controlled and limited. Equipment that is degraded (owing to leaks, corrosion spots, loose parts or damaged thermal insulation, for example) shall be identified, reported and corrected in a timely manner.

9.77. There shall be a programme of monitoring for material degradation for vessels and containers holding mixtures of corrosive chemicals with fissile or highly radioactive substances.

9.78. The operating organization shall be responsible for ensuring that the identification and labels for items important to safety, rooms, piping and instruments are accurate, legible, well maintained, and employ compatible materials and inks.

MAINTENANCE, PERIODIC TESTING AND INSPECTION

Requirement 68: Maintenance, periodic testing and inspection

The operating organization shall ensure that effective programmes for maintenance, periodic testing and inspection are established and implemented.

9.79. Maintenance, periodic testing and inspection, shall be conducted to ensure that structures, systems and components important to safety are able to function in accordance with their design intent and safety requirements, in compliance with the operational limits and conditions, and support the long-term safety of the facility. In this context, maintenance includes both preventive and corrective actions.

9.80. There shall be documented programmes based on the safety assessment report for the maintenance, periodic testing and inspection of all items important to safety. It shall be ensured by means of these programmes that the level of safety is not reduced during their performance.

9.81. The maintenance, periodic testing and inspection programmes and performance shall be reviewed at regular intervals to incorporate lessons learned from experience, see Requirement 76. All maintenance, periodic testing and inspection of items important to safety shall be carried out following approved procedures.

9.82. The procedures shall specify the measures to be taken for any changes from the normal facility configuration and shall include procedures for the restoration of the normal configuration on the completion of the activity.

9.83. Non-routine inspections or corrective maintenance of items important to safety shall be performed to a specially prepared plan and procedures. In-service inspections conducted for safety purposes and on a programmatic basis shall be carried out in a similar manner.

9.84. The frequency of maintenance, periodic testing and inspection of individual structures, systems and components shall be adjusted on the basis of experience and shall be such as to ensure adequate reliability. The operating organization shall assess the results of maintenance, periodic testing and inspection, and incorporate the feedback for continuous improvement.

9.85. The operating organization shall take actions to minimize the risks associated with maintenance during shutdown (inter-campaign periods).

9.86. Any failure to comply with these requirements shall, in a timely manner, be recorded, investigated, reported to the regulatory body in accordance with national requirements and effective, improvement action taken to prevent recurrence.

NUCLEAR CRITICALITY SAFETY

Requirement 69: Operational criticality safety control

All operations with fissile materials shall be carried out to maintain an adequate margin of sub-criticality in all operational states including conditions that are referred to as credible abnormal conditions, or conditions included in the design basis.

9.87. The criticality safety programme shall ensure that operators are aware of the criticality hazard and all operations to which nuclear criticality safety is pertinent are governed by approved procedures. Operators shall be educated and aware of the conditions that may cause a criticality. The procedures shall specify all the parameters that they are intended to control and the criteria to be fulfilled. The programme shall set limits for quantities of fissionable material in transfers and at appropriate other points in processes. Prior to changing the location of process equipment or its process connections, or of neutron reflectors, the criticality assessment shall be updated to determine whether such a change is acceptable.

9.88. Depending on the risk arising from accumulations of fissile material, including waste and residues, a surveillance programme shall be developed and implemented to ensure that uncontrolled accumulations of fissile material are detected and further accumulation is prevented. Deviations from procedures and unforeseen changes in process conditions that affect nuclear criticality safety shall be reported to the senior management and shall be investigated promptly. The regulatory body shall also be informed. Action shall be taken to prevent their recurrence.

Enriched uranium fuel fabrication facilities

9.89. In addition to the requirements established above, the following requirements for enriched uranium fuel fabrication facilities shall be met;

- (a) For the transfer of uranium powder or uranium solutions in a uranium fuel fabrication facility, 'double batching' (i.e. the transfer of two batches of fissile material instead of one batch in a fuel fabrication process) shall be prevented by design and by means of administrative control⁶ measures.
- (b) If uranium has to be removed from vessels or pipe work, only approved containers shall be used.
- (c) If the facility is designed to produce in parallel fuel pellets of different enrichments, operations shall be managed to exclude the mixing of powders, pellets and rods of different enrichments.
- (d) The process material balance shall be verified and controlled.

MOX fuel fabrication facilities

9.90. The following requirements for MOX fuel fabrication facilities shall be met;

- (a) If PuO₂ or MOX powder has to be removed from equipment, only approved containers shall be used.
- (b) In normal operations a number of parameters shall be measured and controlled to prevent a criticality. These parameters shall be of high integrity and shall be calibrated against known standards. Changes to computer codes and data shall be controlled to a high standard by means of the management system.
- (c) The process material balance shall be verified and controlled.

Conversion and enrichment facilities

9.91. The following requirements for conversion and enrichment facilities shall be met;

- (a) Where there could be high concentrations of hydrogen fluoride in the product stream of an enrichment facility, the pressure shall be maintained below the vapour pressure of hydrogen fluoride at that temperature to avoid the condensation of hydrogen fluoride during crystallization (desublimation) of UF₆ in a cylinder or intermediate vessel.
- (b) If uranium has to be removed from vessels or pipe work, only approved containers shall be used.
- (c) In the active decommissioning of conversion facilities and enrichment facilities, before wet cleaning, loss of criticality control shall be prevented by means of the following process, which may be iterative:
 - Non-destructive monitoring⁷⁰ or visually checking for uranium hold-up;
 - Proceeding to dry cleaning in the event that uranium hold-up is detected.
- (d) Special procedures shall be implemented to ensure that criticality control is maintained when dismantling equipment whose criticality is controlled by geometry.

Fuel reprocessing facilities

9.92. The following requirements for fuel reprocessing facilities shall be met;

- (a) Procedures for the transfer or temporary movement of fissile material during operational states (including maintenance) shall be defined.
- (b) In particular, fissile material shall not be collected in containers unless they have been specifically designed and approved for that purpose, particularly waste materials which have not been monitored for fissile content.
- (c) All transfers of fissile material including waste shall be in accordance with the criticality safety requirements of both the sending area and the receiving area and shall be certified as such by the sending facility and accepted by the receiving facility prior to sending.
- (d) Wash-lines and chemical feed lines for vessels and boxes containing fissile material shall be subject to appropriate technical and administrative controls, including when not in use.
- (e) Specific provisions shall be provided to reduce the risk of accumulation of organic phase in tanks that handle aqueous solutions containing fissile material and to detect such accumulations, where necessary.
- (f) Non-fissile chemical reagents that are important to process chemistry shall be assessed. If addition of either the wrong composition or the wrong quantity of a chemical reagent could pose a criticality hazard, then this shall be controlled.

⁷⁰ Typically by measurement of gamma or neutron particles

Research and development nuclear fuel cycle facilities

9.93. The following requirements for nuclear fuel cycle research and development facilities shall be met;

- (a) When handling fissile material, operational limits and conditions that control criticality safety shall be rigorously applied.
- (b) Criticality hazards may be encountered during maintenance work. If fissile material has to be removed from equipment only approved containers shall be used.
- (c) Any wastes and residues arising from experiments or pilot processes, decontamination, or maintenance activities, which contain fissile material, shall be collected in containers with a favorable geometry and stored in dedicated criticality safe areas.

RADIATION, EFFLUENTS AND WASTES

Requirement 70: Operational radiation protection programme

The operating organization shall establish and implement a radiation protection programme.

9.94. The operating organization shall ensure that the radiation protection programme is in compliance with the requirements of Ref. [2]. The operating organization shall verify, by means of surveillance, inspections and audits, that the radiation protection programme is being correctly implemented and that its objectives are being met. The radiation protection programme shall be reviewed on a regular basis and updated if necessary.

9.95. The radiation protection programme shall ensure that for all operational states and design basis accidents, doses due to exposure to ionizing radiation in the facility or doses due to any discharges of radioactive material from the facility are kept below authorized limits and are as low as reasonably achievable.

9.96. There shall be sufficient, independent radiation protection staff and resources available to the operating organization to provide guidance on, and ensure compliance with radiation protection regulations, standards and procedures, and safe working practices.

9.97. Radiation exposures shall be subjected to dose constraints and reference levels, as appropriate, that are set or approved by the regulatory body (or another competent authority) for the purpose of ensuring that the relevant limits for doses and discharges are not exceeded. In all operational states, the main aims of radiation protection shall be to minimise exposure to radiation and to keep doses below the dose constraints to comply with the fundamental safety objective.

9.98. For accident conditions, the radiological consequences shall be kept low by means of appropriate engineered safety features and the measures provided for in the emergency plan.

Control of occupational exposure

9.99. All workers who may be occupationally exposed to radiation at significant levels shall have their doses measured, recorded and assessed, as required by the regulatory body or other competent authority, and these records shall be made available to the regulatory body and other competent authorities as designated in the national regulations.

9.100. The sampling devices, sample transfer methods, sample storage and the analytical laboratories shall be designed to minimize doses to workers.

9.101. Adequate time, distance and shielding requirements shall be instituted for workers handling and inspecting radioactive materials in storage who could potentially be exposed to significant cumulative radiation.

9.102. Appropriate radiation monitoring equipment, including fixed or mobile monitors, shall be provided at the facility to ensure that there is adequate radiation monitoring in operational states and, as far as is practicable, in accident conditions. Due to the wide range of radiation types and physical and chemical forms of radioactive materials the type of monitor used both fixed and mobile shall be specified by suitably qualified radiation protection personnel.

Control of contamination

9.103. The spread of radioactive contamination shall be controlled and minimized as far as reasonably achievable. Access to areas where contamination levels may lead to high doses for workers shall be restricted and the level of control applied shall be commensurate with the hazard (Ref. [2]). Close attention shall be paid to the confinement of fine radioactive powders and aqueous solutions containing thorium, plutonium, enriched uranium or other radioactive concentrates.

9.104. During operation (including maintenance intervention) the prevention of internal exposure shall be controlled by both physical and administrative measures, limiting the need to use personal protective equipment as far as practicable. Adequate ventilation and/or respiratory protection shall be provided for protecting workers and for controlling the spread of contamination when equipment and containers containing radioactive material such as UF₆ cylinders are opened;

9.105. In particular, where there is a likelihood of exposure that cannot be limited by design, the workers shall be provided with personal protective equipment to protect against the hazards likely to be encountered.

Requirement 71: Management of radioactive waste and effluents

The operating organization shall establish and implement a programme for the management of radioactive waste and effluents.

9.106. A facility shall be operated so as to control and minimize, as far as reasonably achievable, the generation of radioactive waste of all kinds in terms of both activity and volume to facilitate the management of radioactive and associated hazardous waste.

9.107. The programme shall include, as appropriate, the collection, characterization, classification, processing (pre-treatment, treatment, and conditioning) and storage of radioactive waste and effluents and transport of waste as well as regular updating of the inventory of radioactive waste. All activities concerning radioactive and associated hazardous chemical waste and effluents shall be conducted in accordance with the management system. Further requirements on pre-disposal management of radioactive waste are established in Ref. [3].

9.108. Discharges of radioactive and hazardous chemical effluents shall be authorized and conducted in accordance with regulations for the protection of the public and the environment. Discharges shall be monitored and the results recorded in order to verify compliance with the applicable regulatory requirements. Records shall be maintained for generation of wastes and effluents, as well as for the storage, processing, classification and transfer of wastes to disposal facilities. They shall also be reported periodically to the regulatory body or another competent authority in accordance with its requirements.

9.109. Approved procedures shall be followed for the handling, characterization, classification, processing, transport and storage of radioactive waste and its transfer to an authorized disposal facility. These activities shall be carried out in accordance with the requirements of the regulatory body.

9.110. An appropriate record shall be kept of the quantities, types and characteristics of the radioactive waste stored or transferred to authorized facilities.

9.111. Where a decision is made to store radioactive waste pending the provision of disposal routes, all the available information for waste characterization shall be retrievable.

9.112. The rigour and frequency of sampling and monitoring regimes for wastes and effluent discharges, including monitoring at source (as near to where the waste is generated as practicable), shall be in accordance with their potential radiological impact and a graded approach.

9.113. A nuclear fuel cycle facility shall have an adequate environmental monitoring program to monitor planned/unplanned releases to environmental media and associated risk or hazard. The program shall include, but not be limited to:

- (a) Establishing background conditions and data before operation;
- (b) Establishing action levels and annual limits for effluent for protection of workers (e.g.; derived annual concentration limits) or annual effluent discharge limits, as well as environmental sampling.

- (c) Establishing onsite/offsite environmental monitoring stations to monitor surface water, groundwater, soil, biota, and flora
- (d) Establishing data record keeping; records of spills/releases, as well as audit and inspection.

OPERATIONAL SAFETY PROGRAMMES

Requirement 72: Operational protection against fire and explosion

The operating organization shall make arrangements for ensuring protection against fire and explosion.

9.114. The arrangements for ensuring fire safety made by the operating organization shall cover the following: adequate management for fire safety; preventing fires from starting; detecting and extinguishing quickly any fires that do start; preventing the spread of those fires that have not been extinguished (e.g. fire zoning of the facility, with adequate fire barriers between zones); and providing protection from fire for structures, systems and components that are necessary to shut down the facility safely. Such arrangements shall include, but are not limited to:

- (a) Application of the principle of defence in depth;
- (b) Control of combustible materials and ignition sources;
- (c) Inspection, maintenance and testing of fire protection measures;
- (d) Establishment of a firefighting capability at the facility;
- (e) Establishment of a site emergency response and fire-fighting capability commensurate with the size, complexity and diversity of the site and the hazard potential of the facility;
- (f) Assignment of responsibilities, and training and exercising of personnel;
- (g) Assessment of the impact of modifications on fire safety measures.

9.115. The arrangements for ensuring fire safety shall be consistent with the nuclear and radiation safety arrangements. Together with the conventional fire safety concerns associated with an industrial installation, fire safety issues relating to nuclear materials shall be assessed.

9.116. In the arrangements for firefighting, special attention shall be given to cases for which there is a risk of release of radioactive material in a fire. Appropriate measures shall be established for the radiation protection of firefighting personnel and the management of releases to the environment.

9.117. The operating organization shall conduct periodic fire safety reviews. These reviews shall include assessments of the vulnerability of safety systems to fire; modifications to the application of defence in depth; modifications to firefighting capabilities; the control of flammable materials; the control of ignition sources; maintenance; testing; and the readiness of personnel.

9.118. The potential for fire or explosion and the control of ignition sources and potential combustible materials, shall be considered, including during maintenance operations.

9.119. An inappropriate response to a fire or explosion at the facility could increase the consequences of the event (e.g. radiological hazards including criticality, chemical hazards). Specific training of external firefighters and rescue staff shall be organized by the operating organization.

9.120. For facilities that produce, use or store UF₆, consideration shall be given to the impact of a fire on a solid UF₆ cylinder (e.g. fire involving a UF₆ cylinder transporter).

9.121. Together with the conventional fire safety concerns associated with an industrial installation, fire safety issues relating to nuclear and associated materials shall be assessed (e.g. for uranium metal and zirconium alloy powder).

Requirement 73: Operational management of industrial and chemical safety

The operating organization shall establish and implement a programme for controlling the risks associated with industrial and chemical hazards to workers involved in activities at the facility are kept as low as reasonably achievable.

9.122. The industrial and chemical safety programme shall include arrangements for the planning, implementation, monitoring and review of the relevant preventive and protective measures, and it shall be compatible with the nuclear and radiological safety requirements. All personnel, including workers, suppliers, contractors and visitors shall be appropriately trained to provide them with the necessary knowledge and awareness of the industrial and chemical safety programme and its interface with the nuclear and radiation safety programme, and shall comply with its safety rules and practices. The operating organization shall provide support, guidance and assistance for the personnel in the area of industrial and chemical hazards.

9.123. In particular:

- Approved procedures and monitoring shall be used to ensure that the concentration in air of hazardous gases (e.g. hydrogen, fluorine) is below required limits, with an adequate margin;
- The operating and maintenance personnel shall be properly and regularly trained in conventional hazards;
- Drills shall be carried out on a regular basis.

Requirement 74: Operational accident management programme

The operating organization shall establish an accident management programme.

9.124. The accident management programme shall be developed that cover the preparatory measures and guidelines to reduce the risk of accidents and to return the facility to a controlled state in which it can be maintained in a safe condition if they occur. The accident management programme shall also

include organizational arrangements for accident management, communication networks and training necessary for the implementation of the programme.

9.125. The accident management programme shall identify any instrumentation needed to monitor the state of the facility and the level of severity of the accident, and any equipment to be used to control the accident or mitigate its consequences.

9.126. Provision shall be made for training personnel in accident management procedures and implementing the accident management strategies, utilising appropriate instrumentation and items of facility that are qualified for operation in accident conditions.

Requirement 75: Emergency plan and preparedness

The operating organization shall establish an emergency plan for preparedness for, and response to, a nuclear or radiological emergency.

9.127. The operating organization shall establish and maintain arrangements for on-site preparedness and response for a nuclear or radiological emergency for facilities or activities under its responsibility, in accordance with the applicable requirements (Ref. [7]).

9.128. Emergency preparedness arrangements shall cover the capability of maintaining protection and safety in the event of accident conditions; mitigating the consequences of accidents if they do occur; protection of site personnel, the public and protection of the environment; coordinating response organizations, as appropriate. Emergency preparedness arrangements shall include arrangements for the prompt declaration of an emergency, timely notification and alerting of response personnel, assessment of the progress of the emergency, its consequences and any measures that need to be taken on the site and the necessary provision of information to the authorities. Requirements for emergency preparedness and response for facilities and activities shall be based on graded approach, and depending on their emergency preparedness categories established in Ref. [7].

9.129. The operating organization shall develop an emergency plan in accordance with the applicable requirements (Ref. [7]) and shall establish the necessary organizational structure, with assigned responsibilities for managing an emergency, and shall coordinate with offsite governmental organizations in the development of off-site emergency procedures to ensure consistency with onsite response plans.

9.130. Emergency plans shall cover all activities planned to be carried out in an emergency. Emergency procedures shall be based on the accidents analysed in the safety analysis report as well as those additionally postulated for the purposes of emergency planning.

9.131. The emergency plan and arrangements prepared by the operating organization shall include the following provisions specific to nuclear fuel cycle facilities:

- (a) Identification of people most affected in a criticality accident;
- (b) Training in, and chemicals for, neutralising and mitigating specific chemical hazards.

9.132. The emergency plan shall, as necessary, include arrangements for responses to emergencies involving a combination of non-radiological and radiological hazards, such as a fire in conjunction with significant levels of radiation or contamination, or toxic and/or asphyxiating gases in conjunction with radiation or contamination, with account taken of the specific site conditions. In particular:

- (a) Emergency arrangements shall be put in place for criticality accidents, releases of hazardous materials (both radioactive material and chemicals), fires and explosions and loss of services (e.g. electrical power supply and coolants);
- (b) In dealing with a fire or release of hazardous materials (e.g. UF₆), the actions taken or the medium used to respond to the emergency shall not create a criticality event or add to the chemical hazard;
- (c) In dealing with an emergency in fuel processing or storage facility, immediate response shall be focused on
 - The chemical toxicity of UF₆ and its reaction products (HF and UO₂F₂), which is predominant over uranium's radio-toxicity;
 - The rapid progression with limited grace period for some scenarios leading to toxicological consequences or contamination by soluble radioactive materials including tritium.

9.133. The operating personnel shall take appropriate action in accordance with established emergency procedures in response to an emergency. Other on-site support service groups and off-site agencies shall be involved as specified in the emergency plan, depending on the nature and the extent of the emergency.

9.134. The emergency response team shall include persons with up to date knowledge of the operations of the facility. All personnel involved in responding to the emergency shall be instructed, trained and retrained periodically as necessary in the performance of their duties in an emergency.

9.135. The emergency plan shall be subject to approval of the regulatory body, as appropriate, and shall be tested in an exercise before radioactive material is introduced into the facility.

9.136. A training programme for emergencies shall be established and implemented, commensurable with emergency preparedness categories and based on graded approach, to ensure that facility staff and, as required, staff from other participating organizations possess the essential knowledge, skills and attitudes required for the accomplishment of non-routine tasks under emergency conditions.

9.137. Exercises shall be conducted at suitable intervals and shall involve, to the extent practicable, all those persons with duties in responding to the emergency. The results of the exercise shall be reviewed and, as necessary, the lessons learned shall be incorporated into revisions to the emergency plan. The

emergency plan and procedures shall be reviewed at specified periods and shall be amended as necessary to ensure that feedback experience and other changes (e.g. contact details of emergency personnel) are incorporated.

9.138. Facilities, instruments, tools, equipment, documentation and communication systems to be used in emergencies shall be kept available and shall be maintained in conditions such that it is unlikely that they would be affected or made unavailable by the accidents postulated to happen.

Requirement 76: Feedback of operating experience

The operating organization shall establish a programme to learn from events at the facility and events in other nuclear fuel cycle facilities and the nuclear industry worldwide.

9.139. The operating organization shall report, collect, screen, analyse, trend, document and communicate operating experience at the facility in a systematic way. It shall obtain and evaluate information on relevant operating experience at other nuclear installations to draw lessons for its own operations. It shall also encourage the exchange of experience within national and international systems for the feedback of operating experience.

9.140. Events with significant implications for safety shall be investigated to identify their direct and root causes, including causes relating to equipment design, operation and maintenance, or to human and organizational factors. The results of such analyses shall be included, as appropriate, in relevant training programmes and shall be used in reviewing procedures and instructions.

9.141. Information on operating experience shall be examined for any precursors to, or trends in, adverse conditions for safety, so that any necessary corrective actions can be taken before serious conditions arise.

9.142. The operating organization shall maintain liaison, as appropriate, with support organizations (manufacturers, research organizations and designers) involved in the design, in order to feedback information on operating experience and to obtain advice, if necessary, in the event of equipment failure or in other events.

10. PREPARATION FOR DECOMMISSIONING

Requirement 77: Decommissioning plan for nuclear fuel cycle facilities

The operating organization shall prepare a decommissioning plan and shall maintain it throughout the lifetime of the facility, unless otherwise approved by the regulatory body, to demonstrate that decommissioning can be accomplished safely and in such a way as to meet the defined end state.

10.1. For a new facility, planning for decommissioning shall begin during the design phase. The decommissioning plan shall be updated in accordance with changes in regulatory requirements, modifications to the structures, systems and components, advances in technology, changes in the need for decommissioning activities and changes in national policies. All operational activities at the facility, including maintenance, periodic testing and inspection, modification and experiments, shall be conducted in a way that will facilitate their ultimate decommissioning. Occurrences at the facility over the transition period, if any, between operation and decommissioning shall be taken into account in updating the decommissioning plan, see Ref. [8].

10.2. For some existing nuclear fuel cycle facilities, the need for their ultimate decommissioning was not taken into account in their design. In this regard, a decommissioning plan shall be prepared to ensure safety throughout the decommissioning process. The plan shall be reviewed by the safety committee and shall be submitted for review and approval of the regulatory body before decommissioning activities are commenced. Documentation of the facility shall be kept up to date and information on experience with the handling of contaminated or irradiated structures, systems and components in the maintenance or modification of the facility shall be recorded to facilitate the planning of decommissioning.

10.3. The decommissioning plan shall include an evaluation of one or more approaches to decommissioning that are appropriate for the facility concerned and are in compliance with the requirements of the regulatory body.

10.4. In developing the decommissioning plan, aspects of the facility's design to facilitate decommissioning shall be reviewed. In addition, all aspects of the facility's operation that are important in relation to decommissioning shall be reviewed. These include any unintentional contamination whose clean-up has been deferred until the facility's decommissioning, and any modifications that may not have been fully documented. The decommissioning plan shall include all the steps that lead to the ultimate completion of decommissioning to the point that safety can be ensured with minimum or no surveillance. These stages may include storage and surveillance, restricted site use and unrestricted site use.

10.5. The decommissioning plan shall include assessment of impacts on safety of decommissioning activities (e.g. decontamination, cutting and handling of large equipment, and removal of some systems), and shall establish measures to address any new hazards that may be created due to these activities.

10.6. Measures shall be established in the decommissioning plan to ensure criticality safety during decommissioning operations, including, as applicable, maintaining criticality control in dismantling equipment whose criticality is controlled by geometry; preventing criticality in the temporary storage of waste contaminated with fissile material that is generated by the dismantling of glove boxes and their contents.

10.7. The decommissioning plan shall take into account the processing, storage, transport, and disposal of the waste that is generated during the commissioning stage. Procedures for the handling, dismantling and disposal of irradiated equipment and experimental devices that require storage and eventual disposal shall be established in advance, or as early as possible if the equipment concerned has already been constructed and these procedures are not in place.

10.8. The decommissioning plan shall include the staffing requirements during decommissioning phase as well as the training and qualification of the personnel involved in the commissioning operations.

10.9. The responsibility of the operating organization shall be terminated only with the approval of the regulatory body.

10.10. The implications for safety of the activities in the transition period, if any, between operation and decommissioning shall be assessed and shall be managed so as to avoid undue hazards and to ensure safety of the facility and site. The safety implications of an extended shutdown before decommissioning, or an extended interruption of the decommissioning schedule, shall be assessed.

10.11. The radioactive material from the post-operational clean-out shall be recovered as far as is reasonably achievable.

10.12. In applying decommissioning actions, including the dismantling of equipment that was used to process fissile material (e.g. vessels, glove boxes), procedures shall be implemented to ensure that criticality control is maintained.

10.13. Criticality safety shall be ensured for the temporary storage of waste from decommissioning that is contaminated with fissile material.

11. INTERFACES BETWEEN SAFETY AND SECURITY

Requirement 78: Interfaces between safety and security

The interfaces between safety and security shall be managed appropriately throughout the nuclear fuel cycle facility lifetime. Safety and security measures shall be established and implemented in an integrated manner so that they do not compromise one another.

11.1. Recommendations on nuclear security are provided in Ref. [17] and [18]. The operating organization shall design, implement and maintain technical and administrative measures, and maintain coordination with State organizations that are involved in safety and security, ensure availability of adequate trained personnel with knowledge and skills on the interfaces between safety and security, and establish and implement a management system integrating, among others, safety and security objectives (see also Section 4).

11.2. The general requirements on the interfaces between safety and security in the areas of regulatory supervision and integrated management system during all phases of the facility lifetime are established respectively by Refs. [4, 5]. Security shall be considered during all phases of the life time of a facility and not only in the siting phase. These requirements apply to nuclear fuel cycle facilities with appropriate use of a graded approach.

11.3. Selection of a nuclear fuel cycle facility site shall be based on both safety and security criteria. Requirements on the interfaces between safety and security in site selection and evaluation of nuclear installations, including nuclear fuel cycle facilities, are established by Ref. [6].

11.4. Interfaces of nuclear safety with nuclear security and safeguards in the design of a nuclear fuel cycle facility are addressed by Requirement 12.

APPENDIX: SELECTED POSTULATED INITIATING EVENTS FOR NUCLEAR FUEL CYCLE FACILITIES

The identification of postulated initiating events shall be carried out in a systematic manner. Although some of the events listed below are not normally considered as initiating events, their occurrence in combination can result in accidents. For instance, consideration shall be given to losses of each normal service followed by a loss of emergency backup to ensure that the consequences would be acceptable under emergency conditions⁷¹.

(1) Loss of Services

- Loss of normal electrical power
- Loss of compressed air
- Loss of inert atmosphere
- Loss of coolant
- Loss of ultimate heat-sink

(2) Loss of reactivity control

- Criticality during fuel handling
- Loss of geometry
- Flooding
- Loss of neutron poison
- Excess reflection or moderation
- Unintentional change of phase
- Failure or collapse of structural components
- Maintenance error
- Control system error
- Over (double) batching

(3) Processing Errors

- Incorrect facility configuration
- Insufficient reagent or coolant, added too slow or too late
- Excess reagent or coolant, added too fast or too early
- Incorrect pressure or gas flow, rupture
- Incorrect or extreme temperature,
- Unexpected phase changes leading to criticality or loss of confinement,
- Function required for safety not applied
- Safety function applied too late

⁷¹ For example, a drop in voltage may cause devices to fail at different times.

(4) Plant and equipment failures

- Failure of confinement or leak
- Inadequate isolation of process fluids
- Blockage or bypass of filter or column
- Spurious actuation of item important to safety

(5) Handling errors

- Hazardous load dropped
- Heavy load dropped on item(s) important to safety
- Safety interlocks failure on demand
- Brakes, overspeed or overload protection inadequate
- Obstructed pathway leading to collision
- Failure of lifting component (hook, beam, cable...)
- Load fixed to floor

(6) Special internal events

- Internal fires or explosions
- Internal flooding
- Security related incidents
- Malfunction in experiment
- Improper access by persons to restricted areas
- Fluid jets, pipe whip
- Exothermic chemical reaction
- Ignition of accumulated hydrogen
- Failure due to corrosion
- Loss of neutron absorption due to corrosion

(7) External events

- Earthquakes (including seismically induced faulting and landslides)
- Flooding (including failure of an upstream/downstream dam and blockage of a river and damage due to tsunami or high waves);
- Tornadoes and tornado missiles
- Sandstorms
- Hurricanes, storms and lightning
- Tropical cyclones
- External explosions
- Aircraft crashes
- External fires
- Toxic spills

- Accidents on transport routes (including collisions into the facility building);
 - Effects from adjacent facilities (e.g. nuclear facilities, chemical facilities and waste management facilities)
 - Biological hazards such as microbial corrosion, structural damage or damage to equipment by rodents or insects
 - Extreme meteorological phenomena
 - Power or voltage surges on the external supply line
- (8) Human errors.

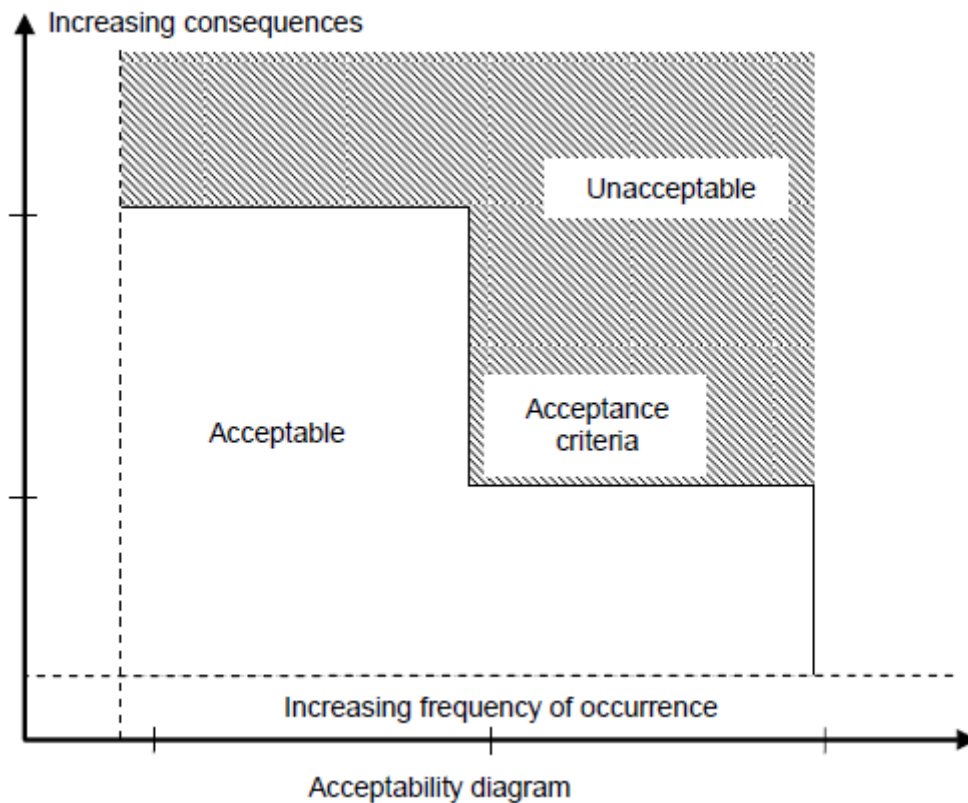
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ANNEX: EXAMPLE OF ACCEPTANCE CRITERIA FOR NUCLEAR FUEL CYCLE FACILITIES

The risks from adverse events could be characterized as tolerable risks or unacceptable risks such that, as the consequences increase, the acceptability in terms of the frequency or probability of occurrence has to decrease. Such limits may be represented in the form of acceptability diagrams such as the following;



Different diagrams may be used for the public and workers, different types of event, or for hazards of different types.

For events in the design basis (or equivalent), a conservative analysis of the scenario is made to ensure there is adequate margin and regulatory limits are not exceeded.

NOTE ON DEFINITIONS

Since the IAEA Safety Glossary (Ref. [9]) was published in 2007, new terminology has entered IAEA use and the definitions of some existing terms have changed. Some of these changes relate to the new concept of “design extension conditions” and related terms.

The following list of terms should be understood on the basis of definitions in the IAEA publications indicated, with editorial substitutions for terms “reactor”, “core” and “package” given in italics;

- **accident conditions** – as defined in Ref. [20].
- **cliff edge effect** – as Ref. [9] with *“power plant”* substituted by *“fuel cycle facility”*.
- **controlled state** – as defined in Ref. [20] with *“plant”* substituted by *“facility”* and *“fundamental”* substituted by *“main”*.
- **design basis accident** – as defined in Ref. [20].
- **design extension conditions** – as defined in Ref. [20] *excluding any reference to core melting*.
- **fissile nuclides and fissile material** – as defined in Ref. [11] with *“in the package or in the consignment if shipped unpackaged”* substituted by *“in the facility”*.
- **natural uranium** - as defined in Ref. [11].
- **plant states** – as defined in Ref. [20] *excluding references to the fuel degradation and the core*.
- **safety system settings** – as defined in Ref. [20].

Other terms (like **administrative control** and **safe state**) that have special meanings in this publication are defined in the footnotes.

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